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The book is dedicated to our beloved family members and the people of developing countries.

Preface

The produced food in the world is sufficient enough to feed all of the human beings. However, almost one-third of the produced food is wasted due to lack of proper post farm processing that leaves almost 13% of the population hungry on a daily basis. The waste of seasonal fruits, vegetables, and grains is significant in developing countries. This scenario is caused due to a number of factors including inadequate preservation facility, lack of food preservation knowledge of the key persons like farmers and producers, and insufficient initiatives from the government and NGOs. Most of the established food preservation started accidentally or by trial and error basis. Later on, the processes were matured with the experience and were passed down from generation to generation. In addition, most of the preservation methods have been practiced for ages, and the innovation of those may be dated back to prehistory. There are diverse nature of mistakes and challenges associated with each type of preservation that prevail around the world. There is no single or shortcut solution to overcome these challenges. In addition, most of the challenges cannot be completely tackled without the participation of all stakeholder associated with food preservation. Multidimensional solutions are required in order to solve the challenges related to food preservation in developing countries. A handbook that encompasses the critical information of common mistakes and challenges in food preservation in developing countries and the solutions of the hurdles can serve a significant role to improve the status of the food preservation conditions in developing countries. The distinct criteria of the book are critical analysis of current preservation technique that is practiced in developing countries, identification of key mistakes and challenges in the current preservation techniques, and proposal of feasible and effective solution approaches to overcome the existing challenges in preservation technique in developing countries.

Rajshahi, Bangladesh

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Contents

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Chapter 1
Foods and Developing Countries

Abstract Food is one of the primary necessities of human. Consumption of any kind of food is not sufficient unless it ensures required nutrition. Safe food is indispensable for humans. The quantity of this highly valuable bounty is not uniformly distributed across the globe. Similar to having low per capita income and low urbanization growth, developing countries produce a relatively lower amount of food than developed countries do. People in developing countries encounter acute hunger on a daily basis. On the other hand, significant loss of food takes place throughout the world. However, the prime causes of food waste vary through countries. A significant amount of food is being wasted at the consumer level in developed countries. On the other hand, postharvest loss accounts for the maximum wastage of food in developing countries. In this chapter, the socioeconomic status of both developed and developing countries has been discussed extensively. Especially, the availability of food in developing countries has been focused in this chapter.

1 Introduction

Any substance that provides nutritional help to the body is known as food. In food, there is an adequate amount of vitamins, fats, proteins, carbohydrates, or minerals, and it is originated from plants or animals. The main function of food is to provide energy, stimulate growth, make the body work, and maintain life.

1.1 Chemicals in Food

Food consists of different types of chemical components including macronutrients and micronutrients as depicted in Fig. 1.1. Macronutrients are the major substances of food such as protein, whereas micronutrient is also a major component but present in a small amount, e.g., vitamins.

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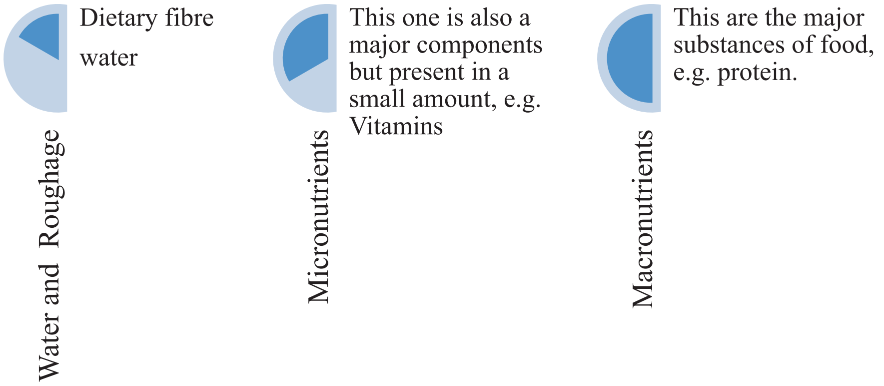

Fig. 1.1 Chemical components available in food

Foods also contain colors, taste, natural toxicants such as cyanide, pharmacologically active components such as steroids, and different contaminants like pesticides. Depending on the numerous chemical components, colors and tastes of food may vary. Moreover, the chemicals inside the food are altered over the course of storage, preservation, and cooking. In other words, chemicals in the foods change persistently in almost every stage of its shelf life.

1.2 Physical Form of Food

The transfer of nutrition from foods to our body significantly depends on the size and shape of the food that we consume. Different size, shape, and state of food ultimately represent the physical form of the food. All of the parameters of the physical form provide different levels of nutrient release from foods that lead to digestion of it by our body. In other words, the size of food particles can affect the extent to which nutrients are digested and made ready for absorption by the body. For example, an equal amount of nutritional value cannot be obtainable from an apple purée and from intact apple. Therefore, in order to retrieve the maximum amount of food nutrition, physical characteristics of food need to be optimized.

2 Food Availability to People

The amount of food is not distributed uniformly to all of the people. It varies with different factors including geographical location, culture, and financial conditions. Therefore, people can be categorized in different ways that ultimately represent the food availability and consumption pattern. For example, the United Nations categorized people into two major categories known as developed and developing countries. This classification considers some core economic aspect such as gross domestic product (GDP), gross national product (GNP), per capita income, and industrialization, the standard of living, and per capita food supply. The countries which have the lack of a free, healthy, and secured atmosphere are termed as developing countries [1].

There are some distinguished features of developing countries. The features include low per capita income, high level of undernourishment and poverty, speedy growth rate of population, low level of human capital, minute level of industrialization and higher level of agriculture, hurried rural to urban migration, informal sector dominance, underdeveloped market, and low level of per capita food supply [2].

Due to the relevancy of the topics, a very brief description of the major characteristics of the developing countries has been presented in the following sections:

- *Lower per capita income*: There is a wide range of inequality in per capita income between the developed countries and developing countries of the world. In 2005, Ethiopia, which is the poorest country of the world, had approximately 345 times lower per capita income than that of Switzerland.
- *High level of poverty and undernutrition*: In developing countries, the level of poverty directly lead to very high undernourishment. It can be depicted from the unnourished people of both sides of the world. About 24% of the people in developing countries are severely undernourished, whereas this percentage falls very low as close to 3% in developing countries.

In the world, approximately one in every nine people is still lacking enough food for living a healthy and effective life, which is 793 million in number. In the last 25 years, about 218 million people suffered from undernourishment, but in the last decade, it was 169 million [3].

The severity of the lack of nutrition has been presented in Fig. 1.2. From the figure, it is observed that in different countries, the number of undernourishment fluctuates. In some regions, the number has been decreased in the last 20 years and somewhere increased.

- *Supremacy of agriculture and low levels of industrialization*: One of the noticeable characteristics of developing countries is that the agriculture sector shares a huge amount in the gross domestic product (GDP) and employment. Most of the workable male population in developing countries along with their female counterpart are engaged in agricultural works.
- *Low level of urbanization*: One striking feature of developing countries is that the share of urban population is much smaller. In developing countries about less than 41% of people lived in urban areas, whereas in developed countries, more than 77% of people lived in urban areas.
- *Lower per capita food supply*: In developing countries the supply of food is also very much lower than the developed countries. In most of the developing countries, supply of food is less or equal to 2000 Kcal per person which is significantly below the average daily consumption of 2500 Kcal per person living in developed countries [4]. Moreover, the waste of food causes further deterioration

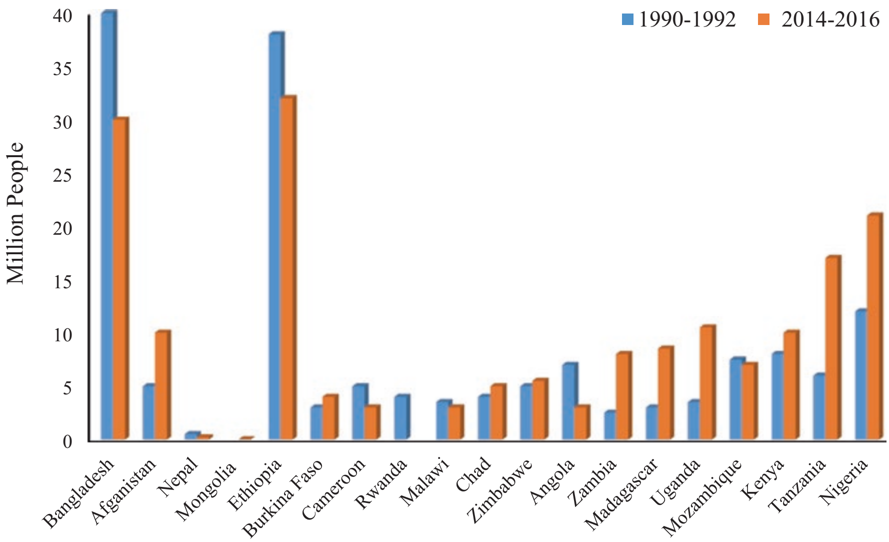

Fig. 1.2 Countries with the highest number of undernourishment [4]

of this shortage of daily intake. In addition, the amount of quantity of food, there is a high discrepancy in nutritional value of those foods consumed by poor and rich people. High essential vitamins and minerals prevail in rich people's daily foods, whereas people of developing counties fill their plates with high carbohydrate-enriched foods that lead to malnutrition.

3 Concerned Developing Countries and Their Status

In this very book, we will explicitly present the food preservation technique of least 38 developed countries based on the per capita income. Prior to revealing the technical details and their associated challenges, some important conditions of those developing countries including per capita income, rural population, employment in the agriculture sector, and undernourished population have been briefly discussed in the following sections. However, Table 1.1 represents the list of developing countries based on the per capita income.

A wide range of inequality in per capita income between the developed countries and developing countries persists nowadays. In developed countries, the average per capita income is $35,000, whereas it is only $2000 in the case of developing countries. This type of wide inequality can also be observed within the poor and rich people of developed countries. Furthermore, as an overview, an agricultural aspect, hunger dimensions, and food supply picture of some of the selected developing countries are shown in Tables 1.2, 1.3, and 1.4, respectively.

Table 1.1 List of developing countries by GDP (PPP) per capita in 2015 [5]

GDP range ($)	Country
2500–3200	Bangladesh, Vanuatu, Cameroon, Kenya, Papua New Guinea, Tajikistan, Lesotho, Tanzania
2000–2499	Nepal, Senegal, East Timor, Chad, Solomon Islands, Benin, South Sudan
1500–1999	Sierra Leone, Afghanistan, Kiribati, Zimbabwe, Uganda, Haiti, Rwanda, Gambia, The Burkina Faso, Mali, Ethiopia
1001–1499	Madagascar, Comoros, Togo, Eritrea, Guinea-Bissau, Guinea, Mozambique
700–1000	Niger, Liberia, Malawi, Burundi, Dem. Rep. of Congo

Although the developing countries utilize most of their lands and engage a majority share of manpower in agriculture, they import more foods than export elsewhere, which indicates ineffective cultivation due to existence of many agriculture-related challenges in developing countries.

4 Food Supply Patterns

Humans need diverse kinds of nutrition for their existence and well-being. All of the required nutrition does not prevail in a single type of foods. A wide range of cereals, roots, pulses, fruits, vegetables, fish, meat, and dairy products encompass all of the essential components for human sustenance. Therefore, a balanced intake of the sets of foods is vital for a healthy living. The subcategories of foods are varied, and determinants for their enrichment of different nutritious value such as meat possess a high level of protein.

In this very issue, developing countries mostly encountered an unbalance food consumption option; eventually, enormous people of this reason suffered for malnutrition.

Figure 1.3 represents the total production of food over the whole world. It is clearly found from the figure that maximum food is produced in industrialized South and Southeast Asia, whereas minimum food is produced in Latin America. Among all food, industrialized Asia is the top fruit and vegetable producer, South and Southeast Asia are the top cereal producer, and the maximum dairy products are produced in Europe.

The above amount of food is mentioned in the stage in which they are ready for consumption. Prior to reaching this final amount, all of the foods encountered a wide range of processing from farm to consumers tables. The processes involved in the food chain have a significant impact on both nutrition and food waste.

A survey found that almost 1.3 billion tons of food is wasted globally, which actually produced for human consumption [8]. The pressure of excess food production is directly caused by food waste. Eventually, the quality of life of both farmers

Table 1.2 An overview of an agricultural aspect of selected developing countries [6]

Name of the country	Population, total (million)			Area harvested (million hectares)			Employment in agriculture (%)			Energy consumption, power irrigation (million kWh)		
Year	1990	2000	2014	1990	2000	2014	1990	2000	2014	1990	2000	2014
Afghanistan	11.7	20.6	31.3	3	2	7	–	–	–	275	275	275
Bangladesh	107.4	132.4	158.5	28	40	55	66.4	62.1	48.1	0	0	0
Benin	5	6.9	10	2	4	7	–	42.7	–	0	14	14
Burkina Faso	8.8	11.6	17.4	3	3	5	–	85.1	84.8	9	9	10
Burundi	5.6	6.7	10.5	2	2	3	–	92.2	–	–	–	–
Cameroon	12.1	15.9	22.8	3	4	7	–	61.3	53.3	0	13	13
Chad	6	8.3	13.2	1	2	3	83	83	–	8	8	9
Dem. Rep. of Congo	2.4	3.1	4.6	1	1	1			35.4	0	0	0
Eritrea	3.3	3.9	6.5		0	0	–	–	–	0	0	0
Estonia	1.5	1.4	1.3	–	1	1	21	7.1	4.7	0	7	7
Ethiopia	53.4	66	96.5	–	8	23	–	89.3	79.3	0	15	15
Gambia	0.9	1.2	1.9	0	0	0	64.7	–	–	0	0	0
Guinea	6	8.7	12	1	2	3	–	76	–	0	4	1
Guinea-Bissau	1	1.3	1.7	0	0	0	–	–	–	–	–	–
Haiti	7.1	8.6	10.5	2	1	2	65.6	50.5	–	0	0	0
Lesotho	1.6	1.9	2.1	0	0	0	–	72.3	–	–	–	–
Liberia	2.1	2.9	4.4	0	1	1	–	–	48.9	–	–	–
Madagascar	11.5	15.7	23.6	3	3	4	–	78	80.4	0	6	6
Mali	8	10.3	15.8	2	2	6	–	–	66	0	0	0
Mozambique	13.6	18.3	26.5	5	6	11	–	80.5	–	–	–	–
Nepal	18.1	23.2	28.1	6	7	9	81.2	65.7	–	0	0	0
Niger	7.8	11	18.5	7	7	10	–	–	56.9	–	–	–
Rwanda	7.2	8.4	12.1	3	3	6	90.1	–	78.8	–	–	–
Senegal	7.5	9.9	14.5	1	1	1	–	45.6	33.7	1	1	1
Sierra Leone	4	4.1	6.2	1	1	4	–	67.3	–	0	0	0
Solomon Islands	0.3	0.4	0.6	0	0	0	–	–	–	–	–	–
Tajikistan	5.6	6.2	8.4	–	1	1	–	–	–	0	0	0
Tanzania	25.5	34	50.8	9	6	10	84.2	82.1	76.5	–	–	–
Uganda	17.5	24.3	38.8	8	10	9	–	68.7	65.6	0	1	5
Vanuatu	0.1	0.2	0.3	0	0	0	–	–	60.5	–	–	–
Zimbabwe	10.5	12.5	14.6	3	4	4	–	60	–	197	305	305

From the above table, it is depicted that more or less half of the population of developing countries are engaged in agriculture-related activities. However, people of these countries encounters severe food shortage along with alarming level of malnutrition.

Table 1.3 Hunger dimensions of developing countries [6]

Name of the country	Dietary energy supply (Kcal/pc/day)			Prevalence of undernourishment (%)			Underweight, children under 5 (%)		
Year	1990	2000	2014	1990	2000	2014	1990	2000	2014
Afghanistan	2072	1792	2087	29.5	45.2	26.8		44.9	–
Bangladesh	2213	2285	2486	32.8	23.1	16.4	61.5	42.3	31.9
Benin	2158	2262	2798	28.1	23.9	7.5	–	21.5	20.3
Burkina Faso	2241	2331	2712	26	26.6	20.7	29.6	35.2	26.2
Burundi	–	–	–	–	–	–	–	38.9	29.1
Cameroon	2055	2133	2625	37.8	32.3	9.9	18	17.8	15.1
Chad	1757	1985	2216	59.8	40.1	34.4	–	29.4	30.3
Dem. Rep. of Congo	2005	2170	2121	43.2	35.9	30.5			11.8
Eritrea	–	–	–	–	–	–	36.9	34.5	38.8
Estonia	–	–	–	<5.0	<5.0	<5.0	–	–	–
Ethiopia	1508	1782	2192	74.8	57.9	32	43.3	42	29.2
Gambia	2522	2536	2893	13.3	14.1	5.3	–	15.4	17.4
Guinea	2434	2346	2619	23.2	27.2	16.4	–	29.1	16.3
Guinea-Bissau	2315	2222	2422	23.1	28.4	20.7	–	21.9	18.1
Haiti	1742	1937	2015	61.1	55.2	53.4	23.7	13.9	11.6
Lesotho	2366	2468	2597	15.6	13	11.2	18.9	15	13.5
Liberia	2268	2084	2348	29	36.5	31.9	–	22.8	15.3
Madagascar	2128	2002	2063	27.3	34.8	33	40.9	35.5	–
Mali	2375	2469	2856	16.7	13.9	<5.0	–	30.1	27.9
Mozambique	1737	1991	2328	56.1	42	25.3	–	21.2	15.6
Nepal	2211	2280	2653	22.8	22.2	7.8	–	43	29.1
Niger	2142	2297	2595	27.7	22.8	9.5	41	43.6	37.9
Rwanda	1792	1781	2259	55.6	60.6	31.6	24.3	20.3	11.7
Senegal	2193	2164	2480	24.5	29.4	10	21.9	20.3	16.8
Sierra Leone	1986	2018	2416	42.8	38	22.3	25.4	24.7	18.1
Solomon Islands	2155	2326	2464	24.8	15	11.3	–	–	11.5
Tajikistan	2046	1953	2153	28.1	38.8	33.2	–	–	13.3
Tanzania	2187	2032	2207	24.2	36.8	32.1	25.1	25.3	13.6
Uganda	2273	2265	2272	23.2	28.4	25.5	–	19	14.1
Vanuatu	2563	2696	2873	11.2	8.1	6.4	–	10.6	11.7
Zimbabwe	1977	2001	2214	42.7	43.7	33.4	–	11.5	10.1

The average dietary energy supply in most developing countries is far more below the average dietary requirement. Consequently, undernourished and underweight children prevail in a large number.

Table 1.4 Food supply picture of developing countries [6]

Name of the country	Food exports (million US$)			Food imports (million US$)		
Year	1990	2000	2014	1990	2000	2014
Afghanistan	95	37	161	170	158	1081
Bangladesh	15	3	71	627	1320	4712
Benin	17	40	373	92	106	1612
Burkina Faso	20	35	176	75	128	367
Burundi	0	2	0	21	23	173
Cameroon	259	172	602	212	215	934
Chad	33	52	39	27	32	154
Dem. Rep. of Congo	14	16	17	67	136	623
Eritrea	0	1	0	30	69	97
Estonia	119	199	977	91	340	959
Ethiopia	10	66	1264	120	296	1393
Gambia	11	13	23	45	60	98
Guinea	18	17	58	104	123	490
Guinea-Bissau	13	50	113	19	35	71
Haiti	12	16	18	187	301	911
Lesotho	6	2	0	112	111	189
Liberia	5	5	31	47	84	308
Madagascar	125	95	274	66	100	340
Mali	92	124	150	88	82	382
Mozambique	31	47	297	191	194	632
Nepal	39	28	170	69	168	829
Niger	50	76	191	97	93	460
Rwanda	0	0	49	42	50	224
Senegal	155	115	318	377	351	1533
Sierra Leone	7	2	30	96	104	278
Solomon Islands	18	40	83	12	14	88
Tajikistan	12	25	41	138	123	572
Tanzania	67	184	726	66	308	1115
Uganda	14	20	446	20	111	793
Vanuatu	11	13	31	10	13	54
Zimbabwe	225	243	147	40	87	1121

and low-income consumer are severly affected. Reduction of post harvest loss can be attained by practicing farm level storage system [9, 10].

From Fig. 1.4, it is seen that most of the process in the food supply chain is manual because the need of manpower is high. Also, the time needed in different stages is also higher due to the manual procedure.

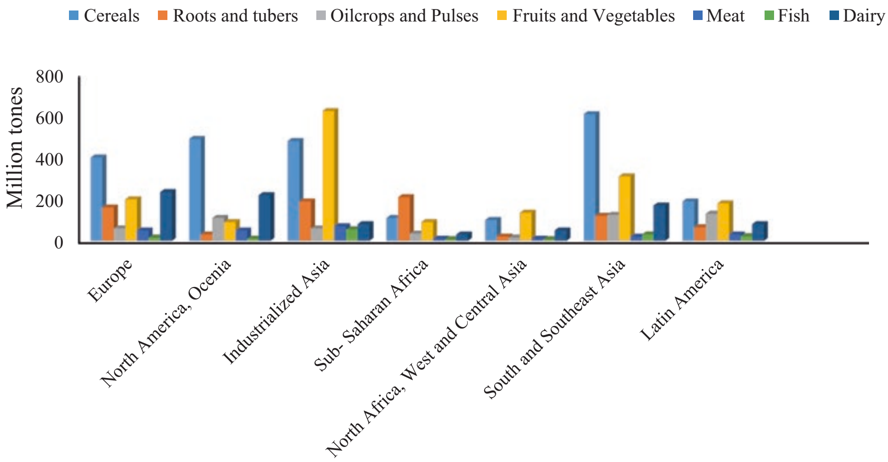

Fig. 1.3 Production volume of each commodity group, per region (million tons). (Adapted from Gustavsson et al. [7])

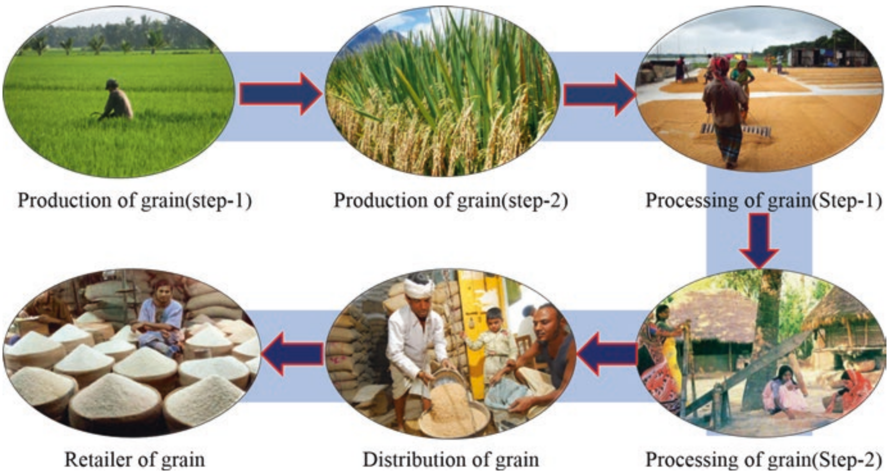

Fig. 1.4 Food supply chain in developing countries

Moreover, as there is no facility of a proper storage system, loss of food is also massive. Due to some unavoidable weather pattern, the need of storage system becomes severe. This unavoidable weather pattern is one of the main reason behind the loss of food. But in the case of developed countries, the picture is the opposite, which is presented in Fig. 1.5. Here the maximum process is machinized, which results in minimum manpower involvement and time savings and ultimately reduces the loss of food production to the distribution stage.

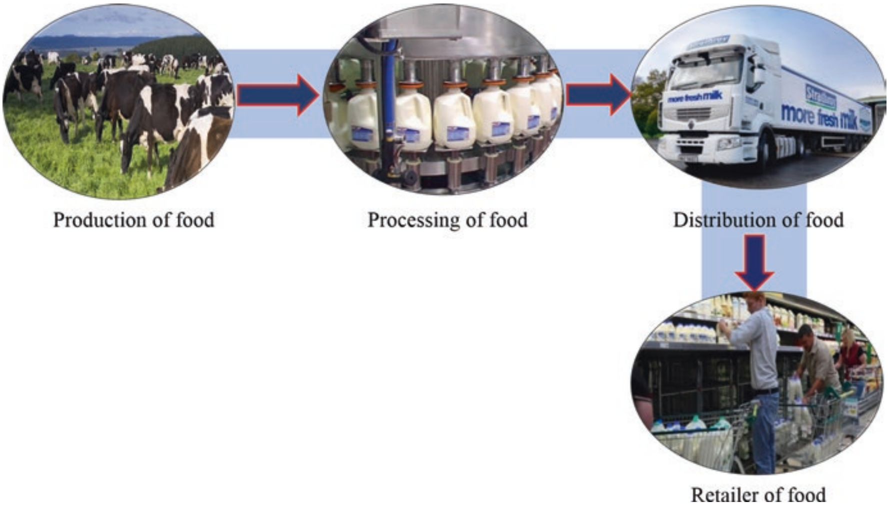

Fig. 1.5 Food supply chain in developed countries

5 Food Wastages

The downfalling of consumable food mass throughout the food supply chain is known as food losses. Food supply chain encompasses production, processing, distribution and consumption [11]. The losses which occur at consumption and disposal stages refer to as "food waste" [11].

Food loss or waste only measured the losses which directly relates to human behavior. Food losses exclude the portion of food products which cannot be eatable or consumable.

5.1 Types of Food Waste

The food supply chain of vegetable and animal commodities is classified into five categories. In every portion of the food supply chain, the waste/loss is estimated. The categories can be described by the way as represented in Figs. 1.6 and 1.7. It is revealed in Fig. 1.6 the losses in different stages of the food supply chain for vegetable commodities and products, whereas Fig. 1.7 shows the losses in different stages of the food supply chain for animal commodities and products.

From Fig. 1.8, it is clearly depicted that different types of foods are wasted at different proportions in various stages of the food chain. Among all these losses, production loss is around 29 percent. The reasons behind the production loss are negative weather and premature harvest due to cash constraints. Postharvest waste

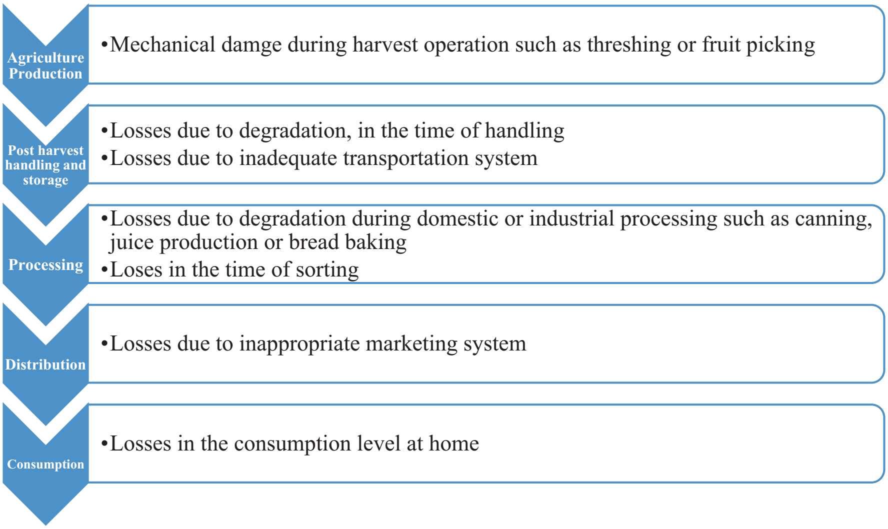

Fig. 1.6 Losses in different stages of the food supply chain for vegetable commodities and products. (Adapted from Gustavsson et al. [7])

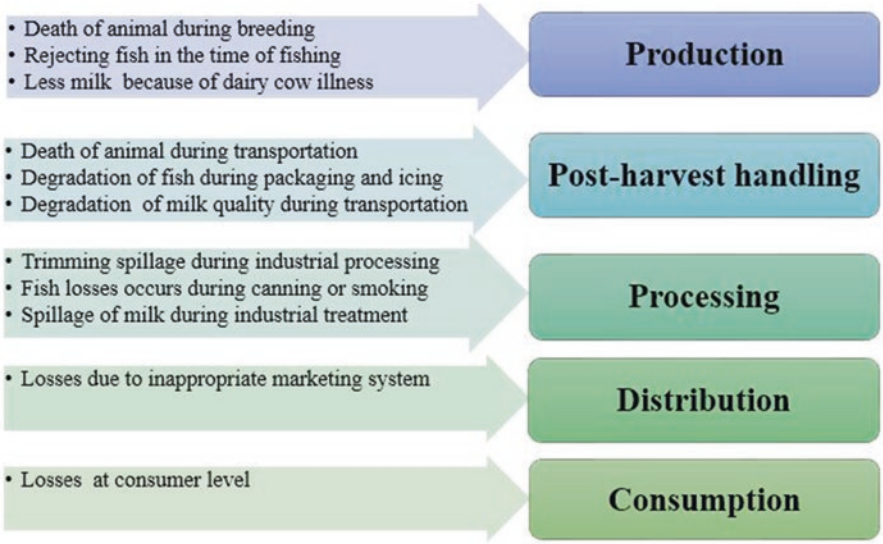

Fig. 1.7 Losses in different stages of the food supply chain for animal commodities and products. (Adapted from Gustavsson et al. [7])

accounts for 15%, whereas the primary reasons for waste are improper packaging, humid weather, and lack of cold storage.

In contrast, inaccurate processing system causes account for 35% total food waste. Poor storage, high seasonality, as well as insufficient financial incentives result in these processing losses. Moreover, the distribution and consumption stage

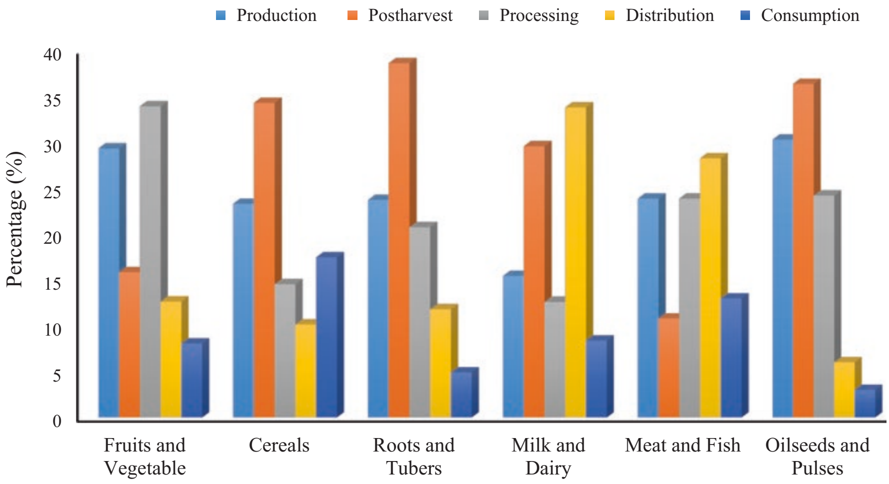

Fig. 1.8 Amount of wastage of different types of foods in various stages in the food chain. (Adapted from Beddington et al. [12])

account for almost 12% and 6%, respectively. Moreover, the distribution and consumption stage account for almost 12% and 6%, respectively.

Although the above description is susceptible to the waste of fruit and vegetable, most of the other types of foods are lost due to the similar types of treatment. Implementation of renewable energy based food preservation techniques can mitigate food scarcity problem in developing countries along with reducing the pressure on global energy.

According to FAO, the wastage of food is a big problem in both developed and developing countries. Figure 1.11 shows the per capita food losses and waste at different regions over the world, in both of the consumption and pre-consumption stages.

It is surprisingly seen from Figure 1.9 that, more than double amount of food is wasted in developed countries in comparison with their developing counterparts. However, there is also a considerable difference present in the production of food in both of the regions which also affects the wastage picture. For example, in the developed world, the per capita food production is almost 900 kg/year which is only 50% in the developing world. The consumer of the developing side of the world losses 6-11 kg/year of food, which is almost 13 times higher in the developed world. The industrialised countries losses more than 40% of the food in the retailer and consumer level, but in developing countries maximum of the losses has occurred in the post-harvest and processing stage which is approximately 40-45% [7].

6 Countries with Agriculture-Based Economy

Agriculture is the largest contributor in the economy of developing countries, even though the share of the sector in national output is declining [13]. In some regions of developing countries, agriculture is taken to as a lifeline to the economy. On

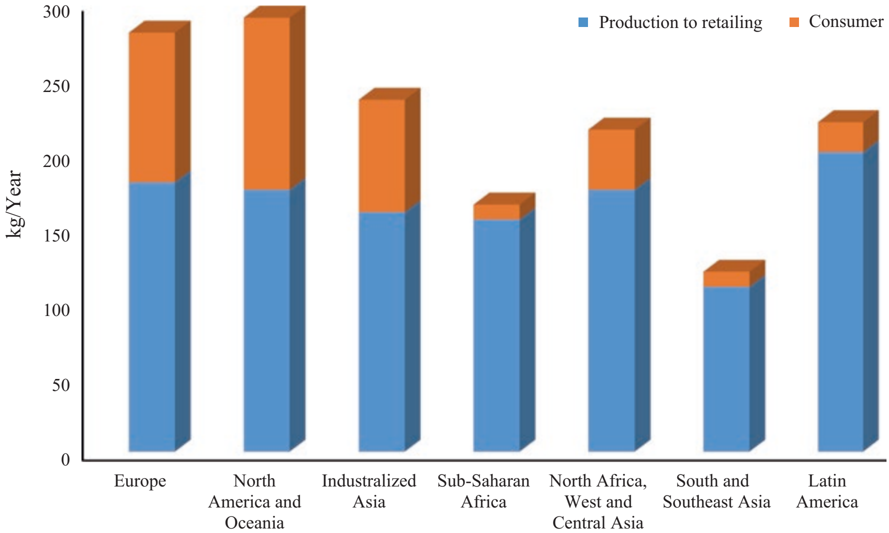

Fig. 1.9 Per capita food losses in several regions throughout the world. (Adapted from Gustavsson et al. [7])

average, one-fifth of the total gross domestic product (GDP) is shared by agriculture in developing countries as shown in Fig. 1.10.

From Fig. 1.10, it is seen that there are three sectors, namely, agricultural, industrial, and service, upon which the share of GDP of the world is depended. Although industrial and service sector put a major impact on the share of GDP, the effect of the agricultural sector cannot be neglected. Especially in the developing countries, Africa and Asia have a great dependency on agriculture, and almost one-fifth of the total GDP is shared by the agricultural sector.

Similarly to the contribution in GDP, the employment of some of the countries dependent on their agricultural sector such as 59.2% employment in Afghanistan is shared by agriculture. Moreover, agriculture plays an important role in enhancing the economic growth in some developing countries. One such instance is Bangladesh where the agriculture is the largest accelerating force to the economy. In Bangladesh, almost 65% labor force is attached with agriculture [14], which also account for 26.13% of the total GDP in Bangladesh since 1985 [15]. The significance of agriculture in the economy of Bangladesh is shown in Table 1.5 [14].

Similar to Bangladesh, agriculture put a huge impact on the economy of Zimbabwe. Although agriculture shares less than 20% on the GDP, the domination of agriculture in Zimbabwe is high as almost 12.5 million people of Zimbabwe which accounts for 75% of the total population depends on agriculture.

In brief, the overall economic status including livelihood, employment, foreign exchange, and GDP of developing countries significantly depend on agriculture. For demonstration purpose, the contribution of agriculture in the different sectors is shown in Fig. 1.11.

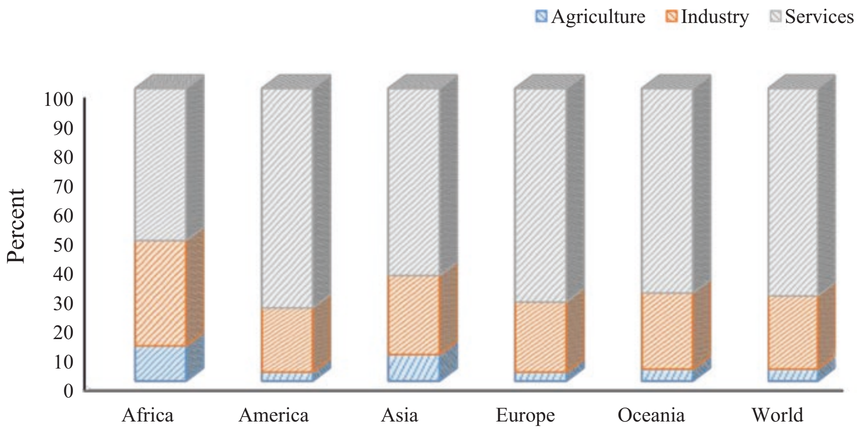

Fig. 1.10 Value added in agriculture, industry, and services, the share of GDP (2013) [6]

Table 1.5 Significance of agriculture in the economy of Bangladesh [14]

Year	1980	1990	2000	2010	2011
Agriculture, value added (% of GDP)	31.55	30.25	25.51	18.59	18.29
Agriculture, value added (annual % growth)	0.16	9.37	7.38	5.24	5.13

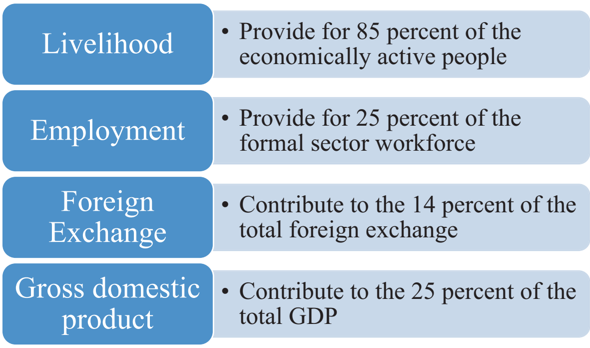

Fig. 1.11 Contribution of agriculture in the different sectors

7 Agricultural Conditions in Developing Countries

When technology develops sharply and it is implemented everywhere in our life, developed countries take advantages of technological advancement in their agricultural sector, whereas very little incorporation of technology with traditional agricultural can be observed in the developing countries. Apart from the technological advancement in processing, developed countries adapted modern strategies in the agricultural conditions, while developing countries cannot get the benefit of scientific advancement in the agricultural conditions such as weather, irrigation, and transportation. A very brief discussion on the overall agricultural conditions has been presented below.

7.1 Weather

The condition of climate encompasses atmospheric temperature, greenhouse gases, and patterns of precipitation. Climate significantly influences water resources, land resources, and biodiversity of both developed and developing countries. These weather-dependent factors have a direct impact on the health and well-being of plants and livestock. Moreover, weather influences insects, disease, and weeds, which in turn affect agricultural production. Therefore, a slight change in climate has a significant impact on agriculture.

Most of the agricultural product is sensitive to change in weather conditions. Even slight changes in temperature, humidity, GHG, and soil condition can damage a huge amount of plant-based food materials productions. For example, the life cycle of grain and oilseed crops may advance more swiftly with the variation in CO_2 and temperature, but they experience immature failure with the variation of these two factors. Especially the failure is found more when the climate variability increases more and precipitation lessens in a huge amount. Livestock production decreases in the summer season due to the higher temperature, but it may partially offset in time of winter season. In response to extreme temperature, production of crops, meat and dairy decreases significantly. Major parameters of upcoming climate change along with the potential impacts on agriculture are given in Fig. 1.12 [16].

7.1.1 Plant Response to Temperature

The plant needs two very specific temperatures for growth and reproduction. The first is named as base temperature, and the second one is named as optimum temperature. For fast growth and reproduction, the required range of temperature must be maintained at any cost. Table 1.6 represents the base and optimum temperatures (°C) for vegetative development and reproductive development of some selected grain and plants [17].

7.1.2 Crop Responses to CO_2

Different crops and vegetable response differently in the changes of the CO_2 content of the atmosphere. Crops are usually of three types, namely, C3, C4, and CAM. Characteristics of the different types of crops are represented in Table 1.7.

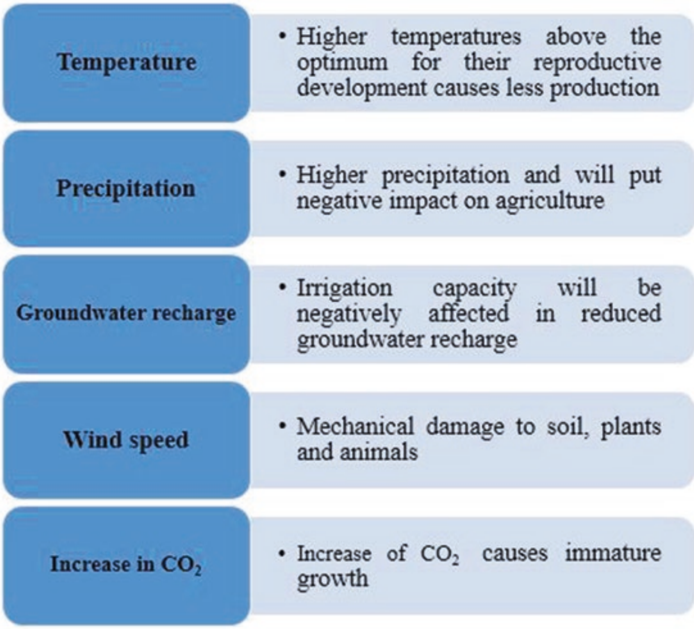

Fig. 1.12 Parameters which might affect climate and agriculture. (Adapted from Jelle et al. [16])

For many C3 crops, when CO_2 is doubled, a 33% increase in the average yield is found, while doubling means an increase from 330 to 660 parts per million (ppm) CO_2 [39]. But for C4 crops, it is only 10% [39]. To increase the advantages of CO_2 optimum fertility, uncontrolled root growth and better control of weeds, insects, and disease are also required [40]. From the elevated CO_2, C3 weeds are more profited than the C3 crop species [41]. Maize, which is a C4 species, is less responsive to increased atmospheric CO_2 [42]. Another C4 crop named Sorghum increases 9, 34, and 8%, respectively, in terms of leaf photosynthesis, biomass, and grain yield while doubling the CO_2 [22]. Soybean which is a C3 crop is quite responsive to CO_2. Soybean increases 39, 37, and 38%, respectively, in terms of leaf photosynthesis, biomass, and grain yield while doubling the CO_2 [43]. Table 1.8 shows the response of some crops due to the doubling of CO_2.

For the vegetative phase of noncompetitive plants, a positive result could be found as there is a greater response to CO2 as temperature rises [51]. This combined effect can put a positive impact on the production of radish (*Raphanus sativus*), lettuce (*Lactuca sativa*), spinach (*Spinacia oleracea*), etc. But there is no beneficial report of the impact of the combined effect on grain yield such as rice [25, 52–55], wheat [56], soybean, etc. Also, there are many negative effects caused by higher CO_2 concentration and higher temperature in terms of fertility.

Table 1.6 Base and optimum temperatures (°C) for vegetative development and reproductive development of some selected grain and plants

Crop	Base temp veg	Opt. temp veg	Base temp repro	Opt. temp repro	Failure temp repro yield	Reference
Maize	8	34	8	34	35	[18, 19]
Soybean	7	30	6	26	39	[20–22]
Wheat	0	26	1	26	34	[23, 24]
Rice	8	36	8	33	35–36	[25, 26]
Sorghum	8	34	8	31	35	[27, 28]
Cotton	14	37	14	28–30	35	[29–32]
Peanut	10	>30	11	29–33	39	[33–35]
Bean	–				32	[36]
Tomato	7	22	7	22	30	[37, 38]

Table 1.7 Characteristics of the different type crops [39–43]

Type	Separation of initial CO_2 fixation and Calvin cycle	Stomata open	Best adapted to
C3	No separation	Day	Cool, wet environments
C4	Between mesophyll and bundle-sheath cells (in space)	Day	Hot, sunny environments
CAM	Between night and day (in time)	Night	Very hot, dry environments

Table 1.8 The response of some crops due to the doubling of CO_2

Product name	Leaf photosynthesis (%)	Biomass accumulation (%)	Grain yield (%)	Reference
Soybean	39	37	38	[42, 44, 45]
Wheat	30–40	–	31	[46, 47]
Rice	36	30	30	[46–48]
Peanut	27	36	30	[33]
Dry bean	50	30	27	[33]
Cotton	33	36	44	[49, 50]

7.2 Transportation

Transportation serves market accessibility to all goods and services by linking the consumers and producers [57]. Transportation has a direct association with food cost, delivery time to customer, and maintenance of food quality [58]. Moreover, transport enhances the interaction between economic and geographical regions as well as the development of the market for agricultural produce. Unlike the modern transportation of developed countries, a very poor condition persists in the transportation system in developing countries. Most of the developing countries use bush paths and unsurfaced rural roads along with a minimal percentage of surfaced rural roads to transport the agricultural product to the market and customers [59]. In order to illustrate the poor transportation conditions of commodities in developing countries, the transportation options of the Republic of Cameroon has been presented in Table 1.9.

Table 1.9 shows the means of transportation in the Republic of Cameroon, where about 16.8% of the people convey their farm commodities on their head. Beside this bicycles, lorries, and motorcycles are also used to transport farm commodities into the market.

7.3 Irrigation

Irrigation is indispensable for increasing crop productivity as water is one of the basic requirements of any form of life whether it is animal or plant. By supplying an adequate amount of water, the productivity of the land can be increased in manifolds [60]. However, irrigation is not as simple as it is thought as it depends on so many things. Some major factors that affect irrigation such as planning and development have been presented in Fig. 1.13 [61].

Although there are several factors affecting progressive irrigation development, with time irrigation system becomes better in most of the developing countries. For instance, many develoving countries like Bangladesh has improved significantly (shown in Fig. 1.14) in the irrigation sector that actually depending on manual irrigation in the last 60 years.

Moreover, freshwater withdrawal for irrigation in developing countries is the number one priority. Even some of the countries like Afghanistan utilize more than 90% of the freshwater that is withdrawal from the ground.

Table 1.9 Means of transportation by road [57]

	Accessible communities		Inaccessible communities	
Option	Frequency	%	Frequency	%
Head (porterage)	65	16.8	164	44.6
Bicycles	12	3	48	13.0
Animal carriage	0	0	0	0
Motorcycle	98	25.3	122	33.2
Motor cars	10	2.6	–	0
Pickup Land Rover	101	26	34	9.3
Minibus	25	6.4	0	0
Lorries/Tipper	77	19.8	0	0
Total	388	100	368	100

Fig. 1.13 Major factors that affect irrigation planning and development

From Fig. 1.15, it is apparent that most of the withdrawal freshwater is used for agriculture in low-income countries.

7.4 Fertilizer

Fertilizer is the nutritional supplement for crops and other plant-based products. As balanced nutrition is vital for the growth of plants, an adequate amount of fertilizer must be supplied if there is any deficiency of nutrition persists in the soil. With the progress of modern research, more and more fertilizer is used in soil nowadays. A sharply rapid increasing trend of fertilizer uses can be observed in both developing and developed countries as shown in Table 1.10 [64].

From the presented data in the table, it is clearly depicted that the use of fertilizer increased manifolds between the years 1960 and 1990 throughout the world. In developed countries, fertilizer utilization reached its peak in the early 1990s, and a slower increase in the use of fertilizer can be observed in the following years, whereas developing countries incorporate more and more fertilizer from 1960 to date in order to reach its peak utilization.

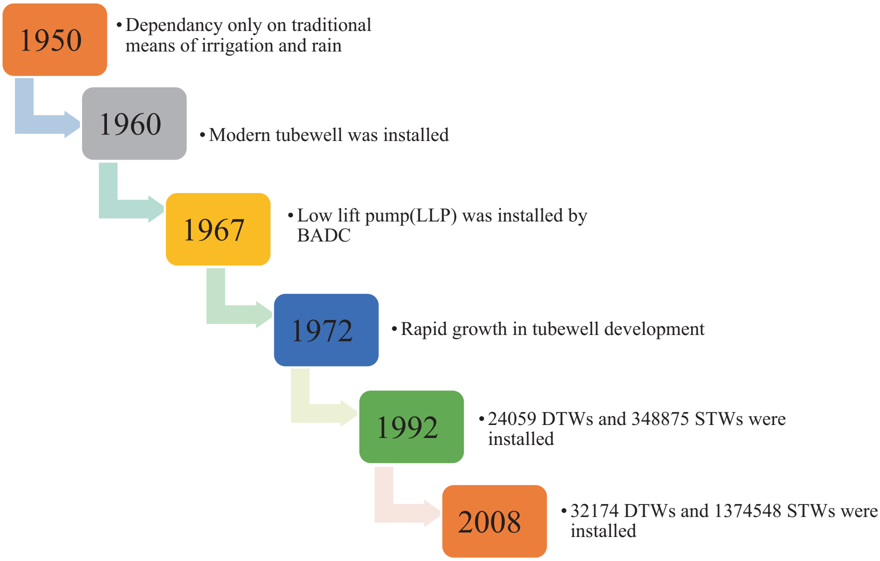

Fig. 1.14 Development in irrigation sector over the last 60 years in Bangladesh [62, 63]

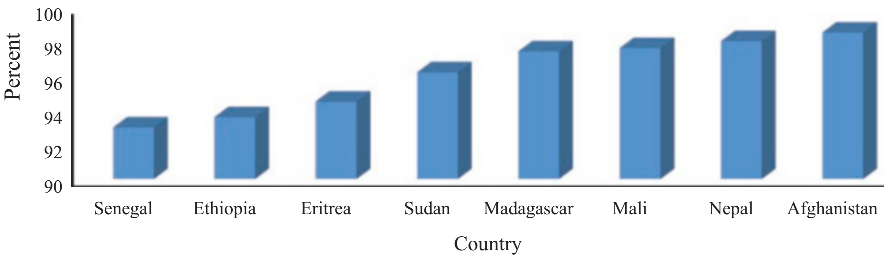

Fig. 1.15 Freshwater withdrawal by the agricultural sector, the share of total (1999–2013). (Adapted from The world Bank, "Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal)", Food and Agriculture Organization, AQUASTAT data. Retrived from https://data.worldbank.org/indicator/ER.H2O.FWAG.ZS, Access Date: 02/03/2019)

Among the nutrients, nitrogen, phosphate, and potash are the most used ones; Fig. 1.16 shows the using trend of fertilizer by the developing countries in the world [64]. Global fertilizer demand is targeted to increase to 86 million tons in developed countries and 122 million tons in developing countries. The slow growth rate reflects a higher base, changing policy environments and limited potential for future growth [64].

As already discussed, upgrading the condition of agriculture is greatly depended on the fertilizer. There are many countries in developing countries which are still facing a severe shortage of fertilizer. For example, sub-Saharan Africa uses only 8 kilograms fertilizer per hectare which is much lower than that of other developing countries [65]. A significantly higher amount of fertilizer is used in the countries of

Table 1.10 Fertilizer use, 1959/60, 1989/90, and 2020 [64]

Region/nutrient	Fertilizer user (million nutrient tons)			Annual growth (%)	
	1959–1960	1989/90	2020	1960–1990	1990–2020
Developed countries	24.7	81.3	86.4	4.0	0.2
Developing countries	2.7	62.3	121.6	10.5	2.2
East Asia	1.2	31.4	55.7	10.9	1.9
South Asia	0.4	14.8	33.8	12.0	2.8
West Asia/North Africa	0.3	6.7	11.7	10.4	1.9
Latin America	0.7	8.2	16.2	8.2	2.3
Sub-Saharan Africa	0.1	1.2	4.2	8.3	3.3
World total	27.4	143.6	208.0	5.5	1.2

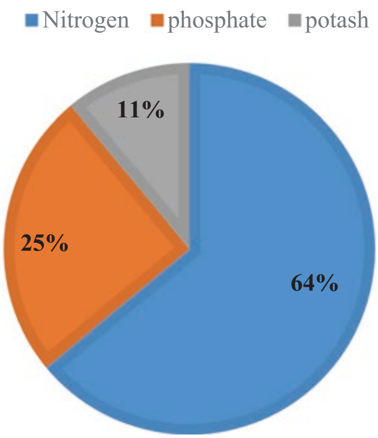

Fig. 1.16 The using trend of fertilizer by the developing countries in the world [64]

developing worlds such as 96 in East and Southeast Asia, and 101 in South Asia are used. This low fertilizer using trend is one of the factors that cause a low agricultural production rate.

7.5 Soil quality

The soil is the storage and distributor of nutrition that is essential for the growth of plants. Continuous cultivation decreases the amount of the nutrition present in the soil. Without proper makeup of those deployed nutrition, the overall soil quality degrades and results in a low rate of agricultural production. The proper amount of required fertilizer can enhance the soil quality and fertility level of the land. Due to lack of technical advance and proper monitoring of the nutrition level of soil, the production rate is found very low in developing countries in recent years. The amount of loss in nutrition presented in Table 1.11 can provide the severity of nutrition loss in some selected countries' arms.

Table 1.11 Estimated soil nutrient losses, African countries, 2002–2004 cropping season [65, 66]

Moderate/low (less than 30 kg/ha/year)		Medium (from 30 to 60 kg/ha/year)		High (more than 60 kg/ha/year)	
	kg/ha		kg/ha		kg/ha
Egypt	9	Libya	33	Tanzania	61
Mauritius	15	Senegal	41	Dem. Rep. of Congo	64
South Africa	23	Burkina Faso	43	Guinea	64
Zambia	25	Cameroon	44	Lesotho	65
Morocco	27	Sierra Leone	46	Madagascar	65
Algeria	28	Togo	47	Liberia	66
		Ethiopia	49	Uganda	66
		Mali	49	Dem. Rep. of Congo	68
		Mozambique	51	Kenya	68
		Zimbabwe	53	Central African Rep.	69
		Niger	56	Gambia	71
		Chad	57	Malawi	72
		Nigeria	57	Guinea Bissau	73
		Eritrea	58	Burundi	77
		Ghana	58	Rwanda	77

kg kilogram, *ha* hectare

Taking all agricultural conditions into account, continuous monitoring and improvement in every sector that is related to agricultural productions are required. Although some of the conditions are beyond our capacity, more technologically based strategies can enhance the agricultural conditions of developing countries.

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Chapter 2
Causes of Food Waste

Abstract Developing countries encounter severe food shortage along with wastage of significant amount of food materials. Food is being wasted almost in every stage of food supply chain including harvesting, postharvesting, processing, and distribution, as well as in consumer level. Due to lack of facilities and availability of proper technology, a higher amount of foods are wasted in developing countries. Reduction of wastage can be possible upon facilitating different initiatives. The wastage of food causes not only scarcity of food but also adverse environmental and economic effects. Therefore, interventions for preventing food waste must be put forward to overcome the hunger problem in developing countries. An extensive discussion on food waste at different steps of the food chain has been presented in this chapter. An adverse effect of food waste has also been presented at the end of this chapter.

1 Introduction

Insecurity in food is an alarming issue throughout the world, and almost 1 billion people are in malnourished problem globally [1]. The wastage of food in the global food supply chain is one of the main reasons behind this alarming issue. From an estimation, it was found about one-third of food is wasted globally [2]. This enormous amount of kilocalories may feed 1.9 billion people [1]. To comprehend the global issue of food wastage, several perspectives like economic, social, and environmental sustainability should be taken into consideration [3]. Figure 2.1 shows the wasted natural resources and production of GHG (greenhouse gases) as an effect of global food losses [1].

Food waste does not only mean the inconsumable part of foods; rather it accounts for the waste of freshwater, land, fertilizer, and energy. In addition to these, wasted food contributes to unnecessarily harmful GHG which results in global warming.

From Fig. 2.2 it has been surprisingly seen that the total economic cost of food wastage for different commodities is 750 billion US$, where vegetables, meat,

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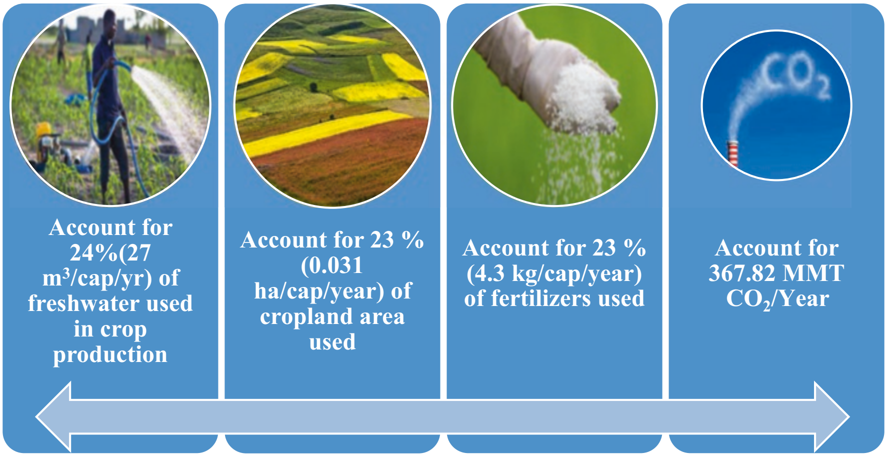

Fig. 2.1 Wasted natural resources and production of GHG as an effect of global food losses

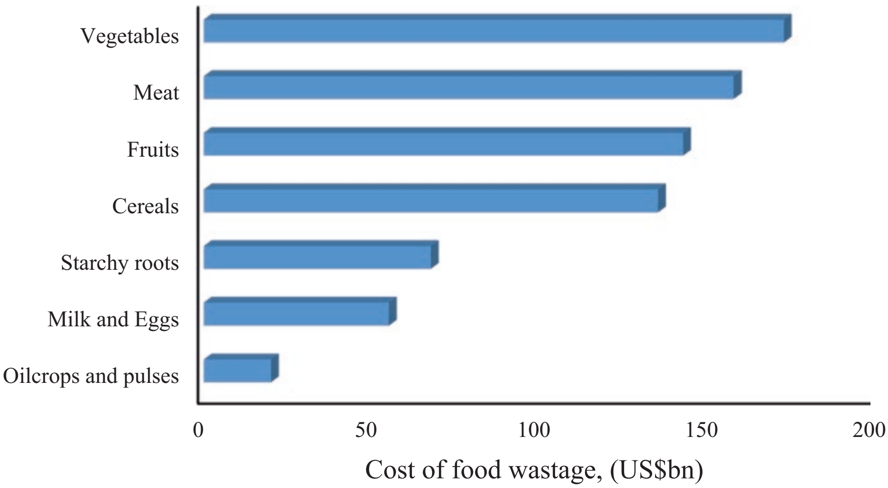

Fig. 2.2 Global economic cost of wasted food, by commodity, in 2007 [4]

fruits, and cereals account for 172.5, 157.5, 142.5, and 135 billion US$. The rest of the economic losses occurred due to the wastage of starchy roots, milk, and eggs, oil crops, and pulses.

The estimated total population throughout the world is around 9.3 billion by 2050 [5–8]. The consumption of food is expected to reach 70% which indicates a really big challenge toward the future food production. Not only the increased population but also the change in food consumption habit of people across the globe causes this increase in food demand [9]. Moreover, the waste of food causes further demand for food production. If food waste can be eliminated or significantly reduced, the extra pressure of producing excess food will lessen remarkably. In this chapter, the pattern of food waste in both developed and developing countries has been discussed. Following this, an extensive discussion on the main reasons for food waste in developing countries has been presented along with the environmental and economic impact of food waste in developing countries.

1.1 Food Waste Scenario

Food wastage occurs because of several reasons and actions associated with the farmers to consumers. In the literature, food waste and food loss are defined with some distinction. However, the term "food waste" as used in this book refers both to so-called waste and loss of food.

It was found that almost 1.3 billion tons of food is wasted globally, which is actually produced for human consumption [10]. Figure 2.3 shows the agriculture production volume, total food waste, and edible food that have been wasted across the globe.

Figure 2.3 represents that all types of food commodities are wasted almost 40% except cereals. For instance, among the produced 560 million tons of fruits, almost 280 million tons are being wasted which is equivalent to 50% of the production of the total fruit.

There are several causes that lead to food waste; however, it varies with the economic status of the countries. Separate dominating factors for food waste are

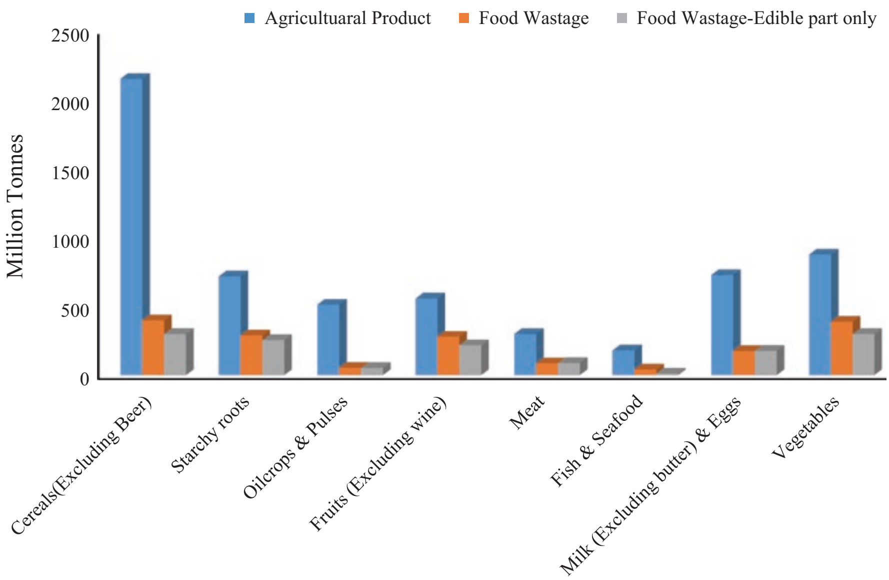

Fig. 2.3 Agriculture production volume vs. food wastage volume [11]

observed in developed and developing countries. A brief overview of food waste in both developed and developing countries has been presented in the following sections.

1.1.1 Food Waste in Developed Countries

Per capita food loss in industrialized nations is as high as food production in comparison with their than the poorer counterparts. Due to the approximately perfect farming system, food storage system and transportation system in developed countries have a lower percentage of food loss compared to the developing countries throughout the food chains except for the consumer level. There are two influencing factors associated with consumers in developed countries, namely, the preference of the cosmetic view of the food and overbuying, upon which the wastage of food is depended. Consumer level food waste in industrialized countries which is around 222 million tons is almost equal to the overall food production in sub-Saharan Africa [10]. Customer level waste in the case of industrialized nations accounts for approximately 40% of the total food waste [10]. Fresh food, leftover food, and uneaten foods are the categories of food which are thrown away by the consumers.

By the householder and primary industry of Australia, around 3 million tons of food is wastage, which is 20–25% of the total national food supply. Consumable foods worth of $5.3 billion are thrown away by the consumer [10]. Household waste depends on household size, household composition, household income, and household demographics as shown in Fig. 2.4.

A growing trend of food waste prevails in developed countries. In America, current food waste reached at 40%; whereas it was 30% in 1974 [12]. The main journey of food waste starts at the retailer level and finishes at the consumer level in America.

Similarly, food wastage problem in Europe is as severe as in America. Almost half of the produced food comprises about 90 million tons of food is wasted each year in EU.

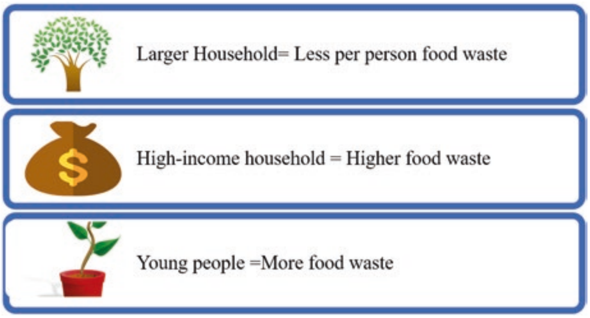

Fig. 2.4 Factors on which household food waste depends

1.1.2 Developing Countries

In developing countries, the amount of postharvest loss is 40%, whereas 25% loss occurs in the preharvest phase [10, 13]. There are many reasons behind the loss of food in developing countries such as poor or low-tech approaches in the farming, storage, and transportation of crops [14, 15]. Further losses occur in the transportation stage due to very poor transportation conditions in countries with low income [16].

Due to non-suitable road facilities, load shedding, and lack of a better storage system, about 40% of food losses occurs in India. Post harvest losses account for 50% of total production in North Korea and Indonesia; whereas the loss is 20% in Africa Due to rat infestations, up to 30% of preharvest losses of maize occur in Kenya each year. In addition, many developing countries encounter 10–20% losses because of pests and pathogens [10].

This is out of the scope of this book to show the whole statistics of food waste across the globe. Just a glimpse of the waste occurs across the world has been presented in order to get a weird picture of how our valuable foods are being wasted. Regardless of the financial state of a country, some common losses occur across the food chain. The main reasons for food waste have been discussed extensively in the succeeding sections.

1.2 Food Waste Across Food Chain

Food supply chain encompasses the field of production, processing, distribution, consumption, and disposal. In all of the stages of the food chain, there is to some extent of waste takes place as shown in Fig. 2.5. However, the severity varies depending on different factors including an adaptation of technology, weather, labor cost, and supply and demand imbalance.

The main factors regarding the loss of food are the unskilled handling and packaging of food, inefficient food storage system, and insufficient on-farm storage facility as well as inadequate market access. The majority of the losses occur in some of the common stage of the food supply chain as shown in Fig. 2.6.

Food wastage in various stages of food chain happens at different proportions in different regions of the world. The proportion varies due to the different conditions persisting in different zones of the globe. In general, different conditions in the same stage of food chain result in different amount of food waste. However, over the time of production, the maximum losses occur almost all of the countries. The production losses account for 25–38% of total food waste. The main reasons behind the production losses are adverse weather conditions and premature harvest for some unavoidable reasons such as cash constraint. Postharvest waste accounts for 10–25%, and the primary reasons for waste are improper packagings, humid

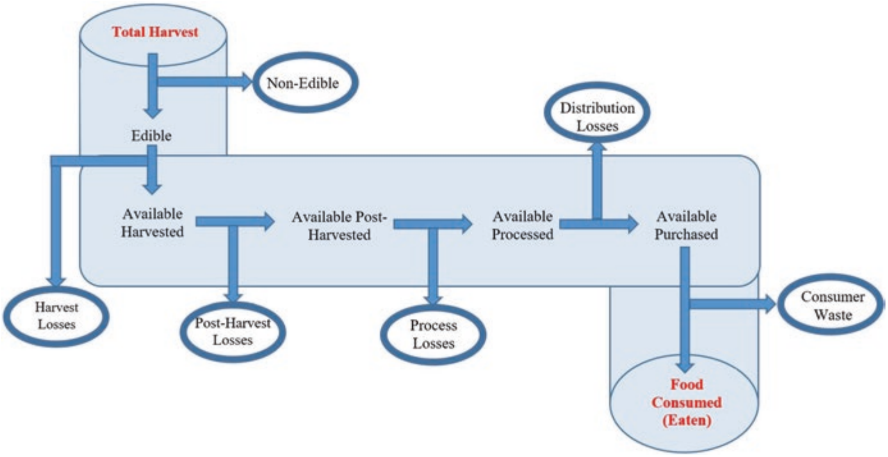

Fig. 2.5 Steps of food waste in the supply chain

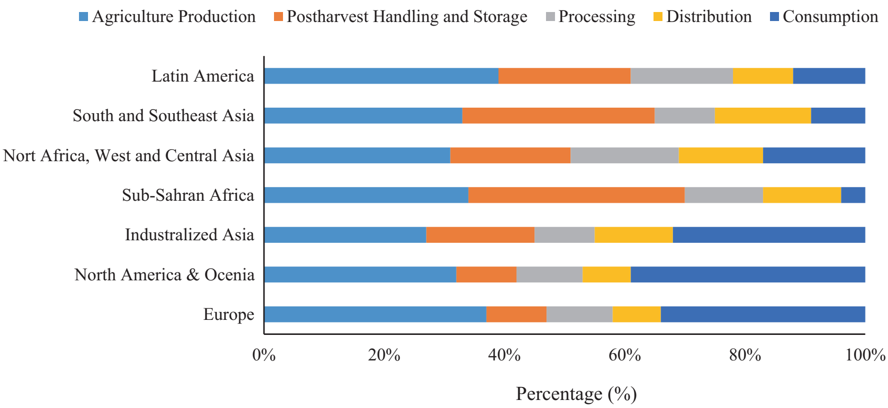

Fig. 2.6 Food losses occur in the food supply chain across the globe. (Adapted from Prakash et al. [17])

weather, and inadequate food storage system. Postharvest waste is significantly higher in developing countries than their developed counterparts.

On the other hand, improper processing system causes 5–15% of food waste. The reasons behind the processing losses are poor storage and high seasonality of the produces. Improper transportation leads to 5–10% distribution level loss of foods. The rest of the foods ranging 10–40% are wasted by the consumer for different reasons including overbuying. The waste at the consumer level is worse in the developed countries than the developing ones.

The abovementioned food waste statistics represent the waste of fruit and vegetable; however, other types of foods depict almost the same trend.

1.3 *Preharvest Factors and Products Left Unharvested*

Diseases associated with biological and biotic entities such as insects, pests, weeds, and microorganisms cause an enormous amount of food losses in the field before harvesting. There are many factors that are responsible for preharvesting food losses. The preharvest food losses factors are shown in Fig. 2.7.

Selection of yield variation, agronomic practices, economic, and environmental factors are the main causes of preharvest losses. However, the severity of these types of losses differs according to the various forms of farming, seasons, and dissimilar production regions. Therefore, substantial dissimilarities are found in food losses in this phase in developed and developing countries.

1.3.1 Selection of Crop Variations

Improper selection of yield variations for the production site and for the target marketplace highly affects the amount of food loss in this phase. The selection of the right varieties that are suitable for a particular place and meet the requirement of the targeted market with superior quality at the appropriate time is essential to reduce preharvest food waste [18].

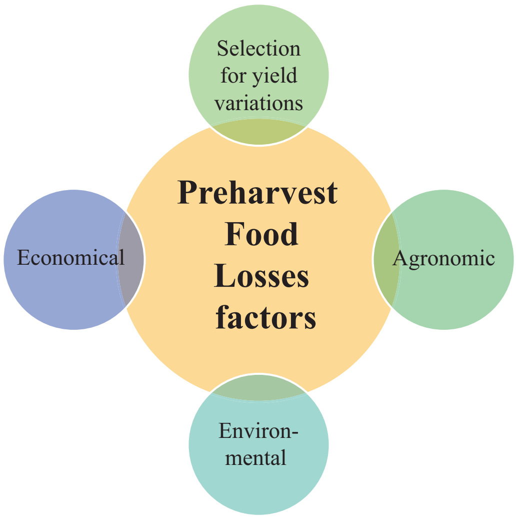

Fig. 2.7 Preharvest food losses factors

1.3.2 Environmental Factors

Negative situations such as heavy rainfall, prolonged cloudy weather, and chilly cold lead to various illness, fragile vegetables, and fruits with a low brix. Figure 2.8 shows the effect of climate change on food safety and nutrition. Physiological disorders such as solar yellowing in sweet paper and cauliflower and sunscald in apples and mangoes can be caused owing to the excessive temperature [18]. Contamination such as aflatoxin and nycotoxin occurs in an unfavorable environment in case of grain that makes food unsafe and finally rejected.

Climate is a significant factor upon which agriculture is highly dependent. The consequence of climate change needs to be considered in consort with other involving factors because they might make it more challenging to grow crops. The frequency and strength of dangerous weather, changes in temperature, and atmospheric carbon dioxide (CO_2) put substantial influences on crop yields.

The effect of changes in temperature is varied from crop to crop according to their optimal temperature for growth and reproduction [19]. If the temperature surpasses the ideal temperature of a crop, yields will be significantly damaged.

High level of CO_2 can put a negative impact on crop yields. Protein and nitrogen contents of crops are also affected due to the elevated CO_2. However, elevated CO_2 levels can increase plant growth in some cases provided that sufficient water and nutrients supply are ensured; otherwise, the crop yields may be declined remarkably.

Excess temperature and rainfall can avert crops from growing. There are also some extreme events such as floods and droughts which can harm the crops and diminish yields enormously [20]. For examples, in 2012 food with $220 million worth damaged in Michigan cherries due to the warm winter and high nighttime temperature [21].

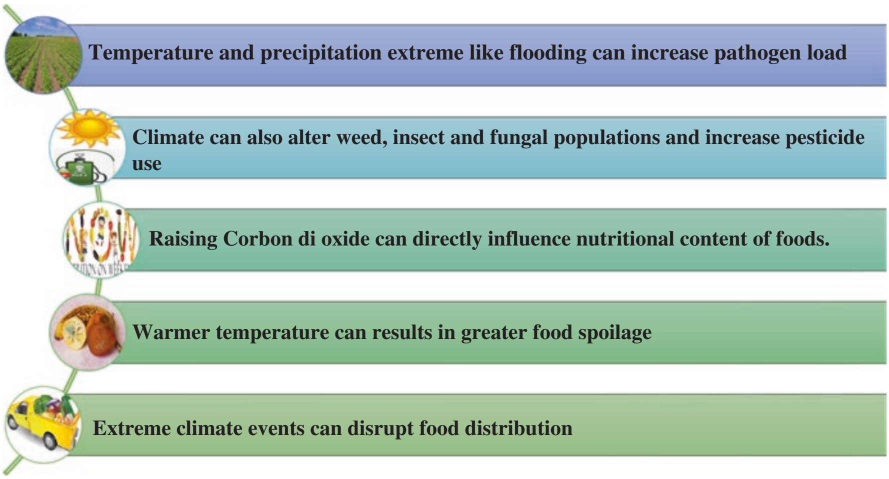

Fig. 2.8 Effect of climate change on food safety and nutrition

Temperature and humidity are the main reliable factors upon which the growth of pests and disease are dependent [22]. In warmer temperature, mistier climates, and elevated CO_2 levels, numerous pests, fungi, and weeds are flourished, which results in numerous amount of crop loss. With the change in climate, the pests and weeds are increasing rapidly, for which farmers need to pay extra cost to protect crops from them [23].

1.3.3 Agronomic Practices

Agronomic practices refer to fertilization, water, and disease management. Customer satisfaction significantly depends on good appearance and high quality, especially for fruits and vegetable selection. These selection factors prominently depended on agronomic practices during the production phase. High losses can be occurred due to poor agronomic practices. There are some pests having latent infestations which do not affect food such as fruits in preharvest stages but only manifest in postharvest stages [18]. In addition, low product quality may be found owing to the poor water and nutrient management.

1.3.4 Economic Factor

Many economic issues such as low market value at the time of harvest and high labor cost and transportation cost lead to food loss in the preharvest stage. Even some producers left the crop in the production site as the returns are not handsome enough than the cost of harvesting and transportation. For example, in 2009, 3.25% of the total production which is almost 17.7 million tons of agricultural products were left in the production site in Italy [24]. The same picture is found in the case of the United States of America where, on average, 7% of planted fields are not harvested each year [25].

Non-equilibrium condition between food supply and demand is one of the major causes of food waste in most countries throughout the world, but the severity is higher in industrialized countries [26]. While this uneven condition between food supply and demand occurs, certain excess harvests are sold at a lower price or simply are converted into animal feeds.

Moreover, particular producers occasionally overproduce to defend against uncertainties of demand from retailers, pest attacks, and uncertainties of weather. There are also some producers who cultivate some extra area to earn some extra money. But sometimes the surplus products are left non-harvested or are harvested and sold to processors or feed industries at lower prices and with lower returns for the farmer [10, 25].

1.4 Waste During Harvesting

Harvesting timing and method, conditions of primary storage, and weather during harvesting are critical factors causing significant losses during the harvesting operations [17].

1.4.1 Immature Crop Harvesting

If harvesting is not performed at crop maturity, an enormous amount of losses occurs during the harvesting operations. Harvesting of the immature crop at high moisture content makes it susceptible to microorganism growth and increases the drying cost which results in a high amount of lower grade grains. Poor farmers in developing countries sometimes harvest premature crops due to a desperate need for money or for food deficiency. Consequently, the food loses its nutritional and economic value and sometimes gets wasted as it is even not suitable for consumption. Nevertheless, in some places of the developing countries where the rains overlap with the harvest season, the food loss is amplified by roting and aflatoxin contamination, which is a key reason for food losses in case of cereals [25, 27].

1.4.2 Primary Storage Approach

In addition, improper food containers that are used for immediate holding of the food cause food loss. In case of fruits and vegetables, the loss is attributed to injured spot on the food surface that leads to degradation of physical properties. Moreover, the ruptured zone also allows the access of pathogens of different types. In the village farming system, the crops are stored in traditional structures after harvesting. The crop is left standing in the field for a long time in the field after harvesting in order to remove moisture by natural convection process. Over this period, the crop can be attacked by pathogens and insects and be taken away by rodents and birds.

1.4.3 Temperature Management

Temperature management is crucial to the preservation of perishable yields such as fruits, vegetables, milk, meat, and fish, and mushrooms as a fairly small variation of temperature may accelerate the growth of the microorganism and result in food spoilage. If the temperature is managed properly just after the harvest, substantial enhancement of the shelf life can be attained. However, most cultivators in developing countries have no access to on-farm cold storage services or sufficient shaded place. Even some cultivators harvest their yields in the hotter parts of the day, which not only generates difficulties in providing appropriate temperature for the yields but results in faster deterioration of food products [28]. Very early morning harvesting is the better time for all types of foods.

1.4.4 Improper Harvesting Technique

Poor harvesting techniques are also a vital contributor to the losses of food that happened during harvesting. In the case of highly perishable commodities such as fruits and vegetables, multiple handling also increases the mechanical damage of food [29]. In developing countries, food is lost due to improper picking techniques. Manual cutting tools including sickle, knife, scythe, and cutters are used in the developing countries for crop harvesting. This manual harvesting is a slow and highly labor-intensive process. Developing countries such as India and Bangladesh encounter labor shortages during the peak harvesting season. This results in enormous losses due to the delays in the harvesting process.

Food should be picked up from the tree/field in the accurate technique so that minimization of food loss can be assured [26]. In addition to manual cutting of grains, ears also contribute food loss. Food picking technique varies for different foods depending on the nature of their attachment with plants. Due to inappropriate harvesting system, a significant amount of mechanical damage may occur especially in case of fruits and vegetables. In order to avoid these unexpected damages, appropriate picking method must be maintained. For instance, the steps described below should be ensured for picking of the apple.

- **Twisting instead of pulling:** A common process for picking apples is to just grasp and pull until they come off the branch; nevertheless this may be destructive to the tree, and it may cause additional apples to drop.
- **Not using apple picker:** An apple-picking device is suitable to reach the uppermost apples on a tree, but it provides a smaller amount control over the way of picking the apples and can simply harm the spur branches.
- **Grasping with the palm:** When picking apples, be sure to grip them in the palm of the hand, rather than using the fingers. The pressure applied by the fingers or by the grip of an apple picker can bruise the fruit.
- **Selecting only ripe ones:** If the apples on the trees aren't fully ripe, they won't be nearly as delicious to eat, and they will also be tougher to remove from the spur branches.
- **Not dropping into baskets:** Because apples are easily bruised, avoid dropping them into the bushel baskets. Instead, carefully set the apples in the basket so that they won't bang against one another.

The above discussion shows the importance of maintaining the proper techniques of apple picking. It demonstrates how a small mistake during picking can lead enormous loss of fresh food. Proper picking techniques are also necessary in maintaining the healthy shape of trees for the future produces.

1.5 Postharvest Waste

Handling, storage, processing, packaging, transportation, and marketing are all associated with postharvest activities. The main steps of harvesting and postharvest system in case of grain are shown in Fig. 2.9.

Quality of food degrades along with the quantitative losses which occur over the postharvesting steps in developing countries. Figure 2.10 can render the severity of quantitative and qualitative aspect of loss over the postharvesting processes of rice in South Asia.

1.5.1 Threshing

Grain type plant-based food materials require threshing to detach the grain from the panicles. Striping, rubbing, impact action, or a combination of these actions is used to execute the threshing process. A variety of options including manual, mechanical, and animal-derived threshold are used to perform threshing operation. In developing countries, manual threshing is the general practice that results in incomplete separation of grain from the panicles, grain breakage, and grain spillage. Due to these, a significant amount of grain is lost in developing countries. Moreover, delaying in threshing due to a shortage of labor in developing countries results in quality and quantity loss. As much as 4% of total production can be lost in case of improper threshing of grain [31].

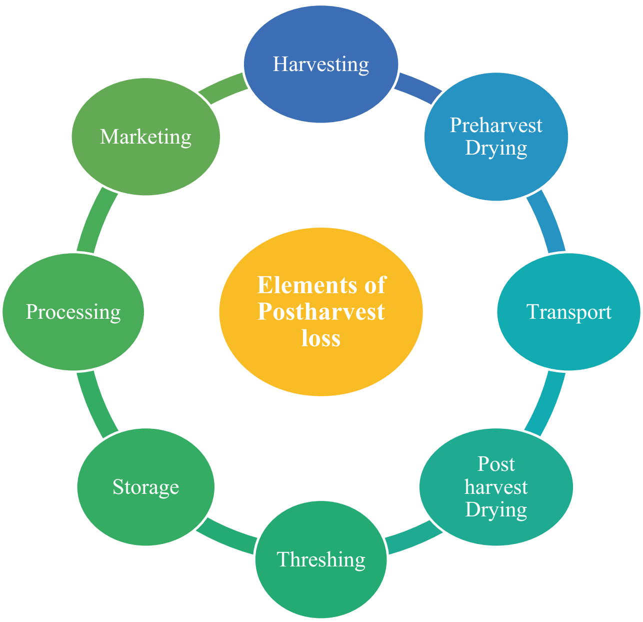

Fig. 2.9 Elements of the postharvest system in case of nonperishable food

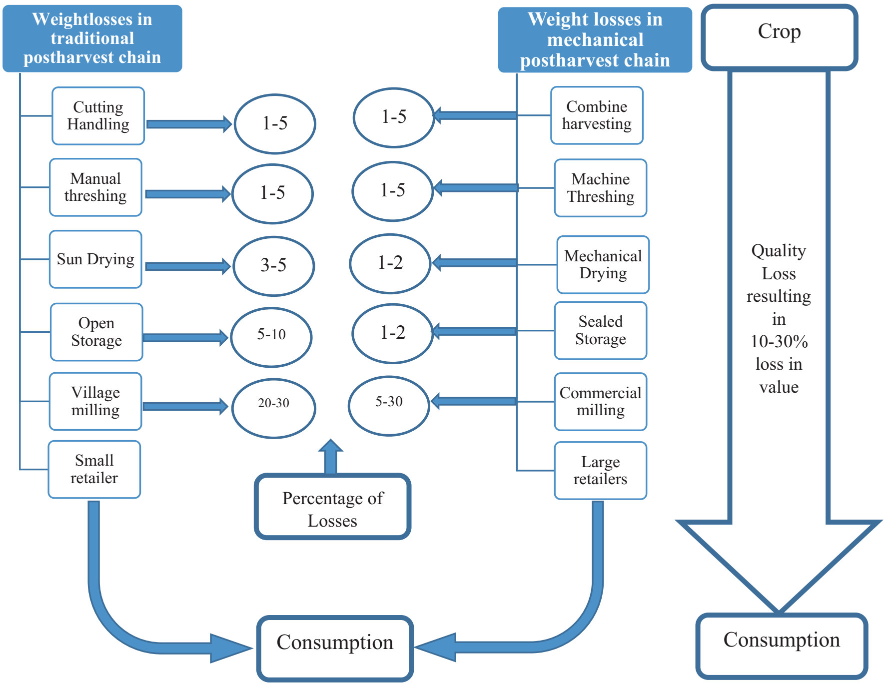

Fig. 2.10 Estimated losses (weight and quality) from the postharvest chain for rice in South Asia (Adapted from [30])

1.5.2 Mechanical Damage

Food loss due to mechanical damage happened in different stages of the food chain including the processes involved during harvesting and postharvesting. Mechanical damage is caused due to mishandling, improper machining, and packaging. Mechanical damages lead to bruises, punctures, cuts, and darkening in color. Inappropriate impact, compression, abrasion, tearing, punching during handling, machining, and packaging cause all of the mechanical damage of food materials. More mechanical damages in foods are observed in developing countries as food handling and packaging are mainly accomplished manually in those countries.

Moreover, loss of edible food portion is observed during different mechanical operations. Inappropriate device and technique result in excess detaching of the edible portion of the food. In addition to this, lack of knowledge regarding the nutritional value of peels of fruits and vegetable and some portion of fish and meat causes waste of a nutritional portion of food by these operations. For instance, these damages are owing to the processes including trimming, peeling, and cutting. For removing indigestible or inedible parts, these processes are performed.

Figure 2.11 shows the trimming, peeling, and cutting off operations of fruits and vegetables.

Fig. 2.11 Trimming, peeling, and cutting of several foods

There are several fruits and vegetables which have a higher concentration of different nutrients in the outer portions. Therefore, peeling fruits and vegetables such as apples, peaches, pears, potatoes, and carrots and discarding the outer leaves of vegetables such as cabbage, spinach, and lettuce result in a higher loss in terms of nutrient quality.

These types of losses are insignificant in developed countries due to their higher processing efficiency of food [32]. The loss is only 5% for fruits and vegetable; on the other hand, it is only 2% of the liquid food in developed countries. However, these losses are enormous in developing countries due to ineffective cutting devices and techniques.

1.5.3 Storage

Storage is the skill of retaining the superiority of agricultural materials or fresh plant-based food materials and avoiding them from worsening for a particular period of time, outside their usual shelf life. In case of some fruits and vegetables and grains, substantial loss occurs in this operation.

The storage losses are affected by biotic factors including insect, pest, and microorganism and abiotic factors such as temperature and humidity. As most of molds growth is susceptible at temperatures of 20–40 °C where the value of relative humidity of the storage system prevails more than 70%. In developing countries such as India and Bangladesh, more than half of the grains are stored in the traditional storage system at the household level for seed and self-consumption [33]. These traditional storage structures are made without any scientific design with the locally available materials including grass and wood. Consequently, the storage shelf life cannot be ensured for a long time as the storage conditions are highly susceptible to mold growth.

1.5.4 Processing

Foods are processed for extending shelf life and making consumable some types of food. In the processing stage of agricultural products, technical malfunctions and inefficiencies process cause waste of food products. This types of losses prevail

Fig. 2.12 Losses of food of different commodities in processing stage [25, 35]

mostly in developing countries due to inadequate implementation of technology in the food processing sector [21, 34]. Due to the diverse nature of food materials, waste occurs in the processing stage differently. Figure 2.12 shows the reason of food losses in processing stages for different commodities [36].

Lack of processing facilities is the prime reason for food waste in the processing stage in developing countries. A large number of seasonal foods get waste due to a lack of processing facilities. The food processing industries in low-income countries occupied with insufficient resources to process fresh foods that come from farm and seas.

1.5.5 Packaging

Packaging is essential for almost all of the stages in the food supply chain. Packaging is indispensable for carrying, preserving, transporting, and keeping perishables of individual products or bulk goods fresh. There are several functions which are done by packaging in the food supply chain to minimize the amount of food waste as shown in Fig. 2.13 [37–39].

Both rigid and flexible materials are used in food packaging in developing countries. Rigid packaging is done by using plastic or glass bottle, cans, pottery, drums, and paper boxes, whereas in flexible packaging, plastic films, foil, papers, and clothes are used. Improper packaging can lead to severe loss of food materials.

Figure 2.14 represents the package manufacturing materials. Low-grade material and inappropriate packaging used in developing countries cause huge amount of food waste. Proper packaging can reduce a significant amount of food losses. For instance, collapsible plastic crates reduce the crushing and bruising damage of fresh produce by 20% than jute bags in Sri Lanka.

1. Protect and Promote the Product	2. Provide information about the health, safety and disposal of the product	3. Allow the suitable conveyance and usage of the product and permit utilization of the product through the supply chain	4. Maintain effective handling of the product throughout the supply chain

Fig. 2.13 Functions performed by packaging

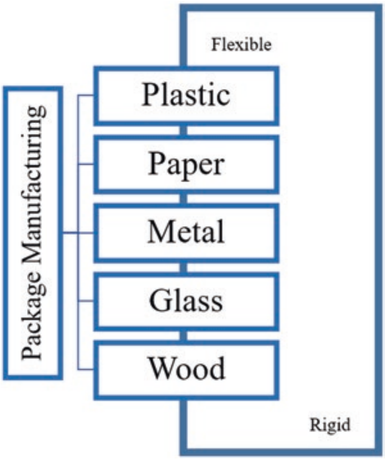

Fig. 2.14 Package manufacturing materials

1.5.6 Transportation and Distribution

After harvesting commodities are required to be shift from one place to another, such as field to processing places, field to storage facilities, and processing place to market [40]. Transportation losses are relatively high in the developing countries due to poor road infrastructure and low-quality maintained modes of transportation. Most of the commodities at farm level are transported in traditional ways such as bullock carts or open trollies in developing countries. Even produces are transported by tricycles, bicycles, and small motor vehicles.

Moreover, in the developing countries, the breakable harvests are replete into the truck to accommodate additional volume without disbursing ample consideration to mechanical damage caused to the harvests due to the deteriorative processes [41]. It is projected that postharvest losses of fruits and vegetables in developing countries are ranging from 35% to 50% yearly owing to poor infrastructure, road, and transportation system [42].

In the case of transportation in long distance, perishable goods necessitate cold environments [43]. Transporting certain farm harvests to a neighboring market by a small truck might not necessitate some superior management, but firm climate control by refrigeration and adequate ventilation is needed while transporting huge quantities over an extensive distance [44]. In the recent time, inconsistent refrigeration problem is really lower compared to the past, but in the developing countries, the picture has not changed a lot yet, which put a negative impact in food losses and waste. Inappropriate transportation vehicles, poor roads, and inefficient logistical management hinder suitable preservation of perishable commodities during transport [45]. For instance, less than 4% of the total fresh product of India is transported by the cold chain in comparison with 90% in the United Kingdom.

Moreover, poor transportation of livestock that is practiced in developing countries is worrying concern as it violates animal welfare most of the time. In Ghana, more than 16% of projected income is vanished owing to incidence of death and sickness or injuries of cattle during transport from farm to cattle market [46]. An analogous case study in central Ethiopia specified that more than 45% of animals were affected (either stolen, died, or injured) during cattle transport [33].

While the food is exported from developing countries to other targeted countries, food losses for the following reasons:

Testing in the port: The shelf life of the imported product is reduced significantly, while it needs to wait days at the ports for testing [47].

Rejected shipments: A bigger difficulty that arises at the distribution phase is that of rejected shipments. If another buyer cannot be found in time, then for rejected perishable shipments all the goods may be dumped [47].

Types of management: Errors in infrastructures and demand predictions, etc. also affect the wastage of food in that stage.

Miscommunication: The deficiency of actual communication among dissimilar agents in the food cycle. If a useful communication scheme is not established to recognize the requirements of the agents in the supply chain, produce losses may effortlessly happen [48].

1.6 Losses in Retail

The demand of excellent quality product significantly affects the losses in supply chain. Quality, shelf-life, and satisfactoriness of the product are highly dependent on the conditions within the retail outlet such as temperature, relative humidity, and lighting [24, 49]. Most of the food commodities types including fruits and vegetables are wasted at the retail stage.

In numerous uncovered markets in developing countries, the sellers are scattering contaminated water onto vegetables and fruits to diminish dehydration under the hot sun. In retail outlets, bulks of fresh-looking displayed commodities are seen as a means to increase the appeal of buyers, who then have the luxury to select by hunt-

Table 2.1 Fresh products waste at the retail level in percentage [50]

Countries	Fruits and vegetables (%)	Meat (%)	Fish and seafood (%)
Europe including Russia (supermarket retail)	10	4	9
North America and Oceania (supermarket retail)	12	4	9
Industrialized Asia (all retail including supermarket)	8	6	11
Sub-Saharan Africa (all retail including supermarket)	17	7	15
North Africa, West and Central Asia (all retail including supermarket)	15	5	10
South and South East Asia (all retail including supermarket)	10	7	15
Latin America (all retail including supermarket)	12	5	10

ing through the bulk. To give the buyer a choice, products like fruit at several ripening stages are bulk together, which contribute to the wastage of food by reducing the shelf life.

Despite of relatively lower retail loss, the total per capita loss is relatively high in developed countries than developing ones. It is reported that approximately 6–11 kg/person/year retail level food loss in developing countries, whereas it is accounted for 95–115 kg/person/year in developed countries [50]. Table 2.1 reflects the amount of loss at retailer level in both developed and developing countries.

It is clearly observed from Table 2.1 that fruits and vegetables get wasted in highest rate, owing to 8–17% of total wasted foods. There are several key factors that cause in-store losses of food commodities [43].

1.6.1 Overstocked Product Displays

Maximum retail stores work under the hypothesis that consumers purchase more from overflowing, completely stocked exhibitions, favoring to pick their commodities from a towering bulk rather than from a scantly occupied bin.

1.6.2 Expectation of Cosmetic Perfection

Numerous consumers choose shops based on the quality of products, and consequently, retailers feel compelled to produce the perfect shape, size, and color which causes a huge amount of food to be repealed.

Overly stringent requirement such as aesthetic views, consumer's preference, and cultural norms causes enormous food as discarded. In supermarkets, high "appearance quality standards" treated as a significant factor for the fresh food products. Particular products are discarded by supermarkets at the farm gate owing to harsh quality values regarding shape, size, weight, and appearance of crops. Also due to specific preharvest factors, some produce are left unharvested when the quality standards (shape, size, the weight of product) failed to meet the certain demand of retailers causes a huge amount of food loss [51].

Too Large Lot Size

Products reach in fixed amounts according to case size. This bounds the buyers to buy more the quantity required. For instance, if a grocer wants 50 grapefruits nevertheless they come in cases of 80, the store is then stuck with 30 extras.

Availability of Fresh Until Closing

Stores are progressively offering more prepared, ready-made food in their buffets. On the one hand, this can be a decent technique to make usage of slightly injured goods if the labor is accessible to organize so. Ready-made food makes up a huge share of food lost at convenience stores, which reject around 25% of the food products [52].

Damaged Goods, Outdated Promotional Products, and Unpopular Items

Goods are similarly rejected owing to injured wrapping or promotions that have passed after different event or hodidays. Furthermore, numerous of the 19,000 or so different food products located on grocery store shelves each year are not widespread with customers and might be rejected when they fail to sell [43].

1.7 Consumption

Consumer attitudes and profusion causes a higher amount of food waste, especially in industrialized countries. Conceivably, one of the most significant causes for food waste at the consumption stage in developed countries is that people merely can afford to waste food. In the last decades, the aggregate of accessible food per person in retail stores and restaurants has increased significantly. Numerous restaurants serve foods at fixed prices that inspire public to fill their plates with extra food than they may essentially require. This eventually results in a substantial amount of food wastage [32, 35, 53]. Similarly, the producers of food produce gigantic sized ready food to eat that makes difficult to a lot of people to finish the meal, which also consequentially wastes food [51]. The total food consumption in different developing countries throughout the world is represented in Table 2.2.

Table 2.2 Total food consumption (Kcal/capita/day) [54]

Location	1961–1971	1971–1981	1981–1991	1991–2001	2001–2007
SSA	2201.32	2210.82	2206.72	2236.89	2310.26
Cote d'Ivorie	2557.44	2696.73	2605.80	2433.52	2493.21
DRC	2282.81	2219.92	2186.48	1788.65	1570.95
Ethiopia	1748.97	1603.88	1626.74	1670.10	1915.49
Ghana	2102.13	1933.96	1927.43	2483.26	283.98
Kenya	2291.84	2334.55	2129.88	2026.83	2033.87
Nigeria	1900.89	1779.06	1961.11	2532.21	2638.89
South Africa	2748.51	2858.69	2860.49	2838.27	2957.96
Tanzania	1733.24	2087.46	2212.02	1965.95	1981.46
Benin	1909.03	1920.56	2054.03	2319.10	2479.38
Burkina Faso	1710.69	1690.92	2113.60	2522.72	2646.42
Burundi	2115.15	2057.77	2892.61	1716.07	1685.40
Cameroon	2055.67	2238.91	2040.74	2060.59	2240.88
Gambia	2309.06	1934.87	2373.52	2283.54	2302.15
Guinea Bissau	1783.83	1913.37	2203.48	2219.08	2251.50
Madagascar	2519.67	2545.81	2350.91	2103.93	2092.43
Malawi	2209.19	2345.11	2036.57	1981.62	2094.39
Mali	1692.84	1617.23	1992.26	2251.50	2523.39
Rwanda	1991.74	2197.15	2037.59	1827.36	2025.80
Senegal	2440.90	2194.54	2221.27	2147.85	2255.88
Uganda	2322.98	2268.48	2203.77	2237.99	2279.20

Across all the countries, the consumption trend is not equal. In SSA per capita, food consumption (measured in kilocalories) has been increasing at a rate of 1% per decade, while Kenya, Cote D'Ivoire, and DRC have been experiencing a decreasing trend. In Kenya, Cote D'Ivoire, and DRC, per capita food consumption is decreased by 3%, 1%, and 9%, respectively [54].

The drivers for household food losses or losses of food in the consumption stage are represented by Fig. 2.15.

The consumer level waste problem is generally a concern in developed countries as food wasted in this stage is insignificant in developing countries as displayed by Fig. 2.16. Limited household income and poverty are the main factors that affect the minimal losses of food in the consumer stage. However, an important factor is that consumers in developing countries usually buy lesser quantities of food products at once, frequently just adequate for meals on the day of purchase.

The gray portion differentiates consumer waste from postharvest losses within regional food loss and waste. In addition, for each group of countries, the area of the rectangle denotes overall regional FLW [10].

Among all the causes of FLW at consumer level, the main driving reasons are mentioned here [55, 56]:

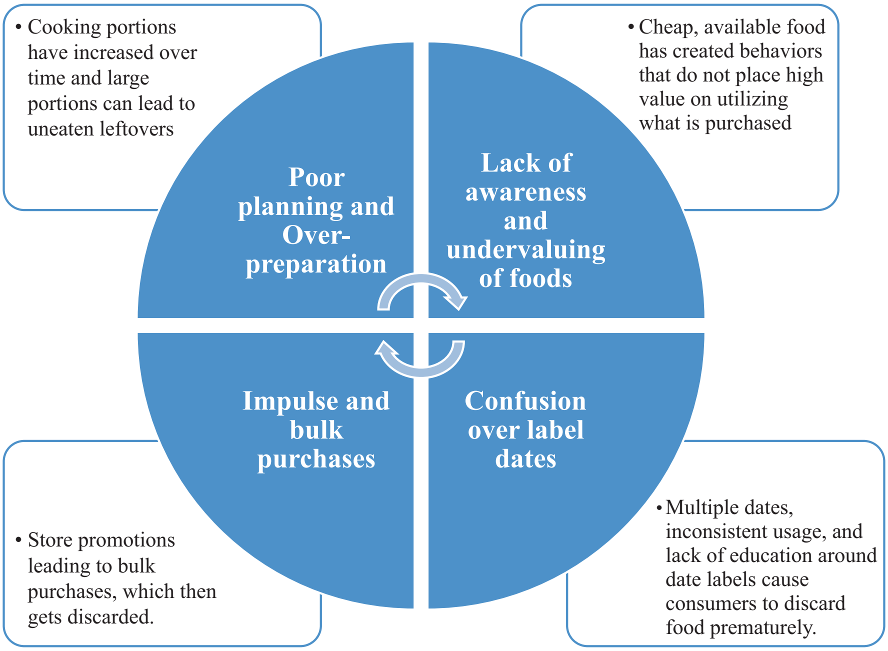

Fig. 2.15 The drivers for household food losses. (Adapted from Gunders et al. [43])

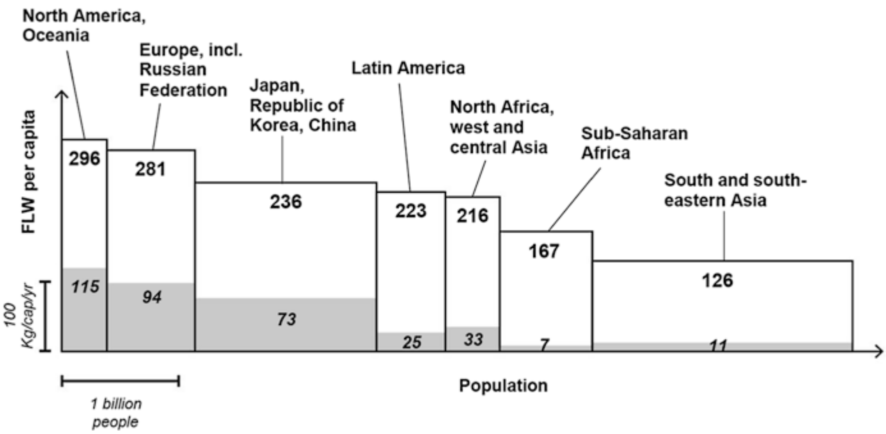

Fig. 2.16 FLW per capita in the different regions of the world [17]

- Purchasing food very early which is not prerequisite instantaneously.
- Discarding food owing to confusion over "best-before" and "expire" dates. Disposal of the food owing to the misconception between "best-before" and "expire" dates
- Poor home food storage facility

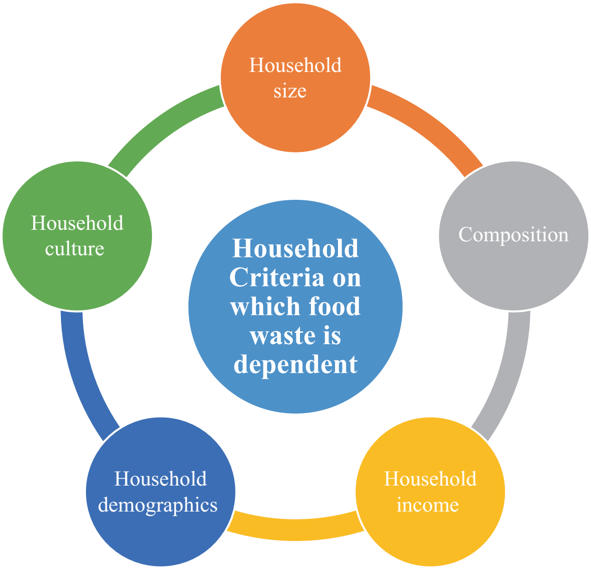

Fig. 2.17 Household criteria on which food waste is dependent [15]

- Excess shares prepared and leaving unconsumed.
- Poor food preparation practices.
- Deficiency of awareness on how to consume leftover foods.

Moreover, there are also some household criteria that are often identified as having an impact on the level of waste in households in developed countries as represented by Fig. 2.17 [15].

Planning, good management, and documenting food waste statistics might substantially diminish FLW.

1.8 Effects of Food Waste

1.8.1 Environmental

Wasted food or agricultural products are the sources of almost 22% of international greenhouse gas (GHG) emissions [3, 57]. Table 2.3 summarizes the GHG emissions owing to the preventable waste food all the way through the life cycles of food commodities. The total emissions from all phases are presented as both combined national emissions and per capita emissions. Figure 2.18 exemplifies the national emissions graphically. All the emissions are testified in carbon dioxide equivalents (CO_2e).

Although the amount of beef wasted is less than 2% of the entire waste by weight, it is responsible for 16% of the total emissions in the United States. This is because

Table 2.3 GHG from avoidable US food waste in 2009 (MMT CO_2/year for all emissions, except per-capita emissions in Kg CO_2/year) [57]

Category	Production + processing emissions	Packaging emissions	Distribution + retail emissions	Disposal emissions	Total national emissions	Total per capita emissions
Beef	17.27	0.10	0.32	0.34	18.03	58.74
Chicken	7.12	0.13	0.43	0.45	8.13	26.49
Other meats	6.17	0.16	0.52	0.54	7.38	24.05
Fish and shellfish	1.33	0.02	0.06	0.07	1.48	4.82
Cheese	2.37	0.05	0.12	0.14	2.68	8.72
Milk and yoghurt	8.60	0.23	0.24	0.34	9.40	30.63
Other dairy	6.89	1.72	1.89	0.20	10.70	34.84
Butter, fats, and oils	2.04	0.35	0.45	0.53	3.37	10.98
Eggs	5.11	0.49	0.65	1.02	7.26	23.66
Sweeteners	1.82	0.14	0.21	0.29	2.47	8.03
Nuts	2.15	1.04	1.13	1.81	6.12	19.94
Legumes	0.20	0.01	0.04	0.07	0.33	1.06
Grains	0.11	0.01	0.03	0.05	0.20	0.67
Vegetables	5.82	0.57	1.68	2.83	10.91	35.53
Fruits and juices	5.67	0.72	3.23	4.75	14.37	46.81
Fruits	4.79	0.50	2.11	2.68	10.08	32.84
Total	77.46	6.23	13.12	16.11	112.92	367.82

of the high emission intensity of beef [58]. Besides beef, all the other animal products have relatively high emission footprints. They make up almost 30% of altogether wasted food by weight but responsible for approximately 57% of the emissions. In contrast, grains, vegetables, and fruits contribute just 31% of the emissions owing to their comparatively low emission footprints although the amount of waste is almost 56% in terms of weight [57].

The decomposition of wasted food causes the emission of methane. In the United States, 23% of all methane emissions occur owing to the food waste [43]. Therefore to avoid the methane production it is obvious to do composting; however, only 3% of wasted foods is composted [59]. The rest of the wastage is gone to the landfill. In reality, food currently signifies the lone major constituent of municipal solid waste reaching landfills, where it steadily converts to methane, which is a greenhouse gas that at least 25 times more influential in global warming as carbon dioxide [53]. Because of the high moisture content and organic nature of food scraps, it decays more quickly than further organics.

Consequently, they create a huge quantity of the methane. From an estimation of an expert, it was found that food scraps contribute 90% of landfill methane emis-

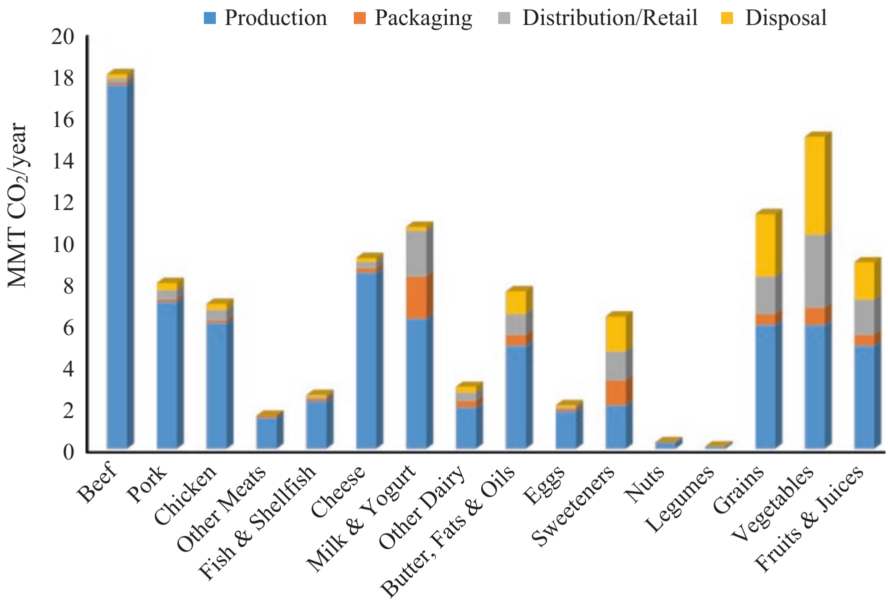

Fig. 2.18 US national GHG emissions from avoidable food waste in 2009. (Adapted from Venkat [57])

sions [60]. Likewise, the same picture is found in case of United Kingdom, wherein in a report it was estimated that greenhouse gas production from the food scraps of the landfill is equivalent to the production of greenhouse gas by one-fifth of all the cars in the country of the road [61].

Composting is a significant technique to cope up with this waste; it lessens methane emissions, recycles nutrients, and raises consciousness about the measures of food being wasted. It is also possible to capture the produced methane for the generation of energy via a process known as anaerobic digestion. There will always be food wastage in terms of organic scraps, no matter how efficient we are. This is why it is very much needed to increase food use efficiency by doing composting in order to lessen the environmental impact of human activity.

1.8.2 Economic

Food waste is becoming an emergent concern due to its adverse impact on the economy and environment. Money spent on groceries is related to the amount of food wasted. It seems that food waste amount is related to financial consequences of food waste. Figure 2.19 displays the economic perspective of reduction of food waste [62]. Food waste reduction is projected beneficial for supply chain members, households, and the entire society if this reduction is translated into monetary saving [62]. However, economic impact calculation of food waste reduction involves the calculations among actors and sectors in the food system [62, 63].

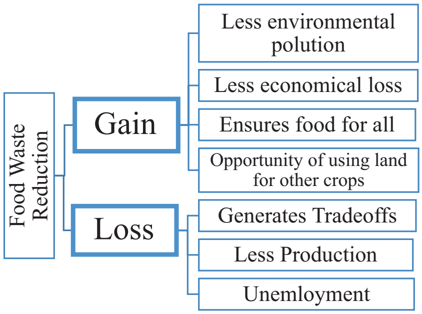

Fig. 2.19 The economic perspective of reduction of food waste

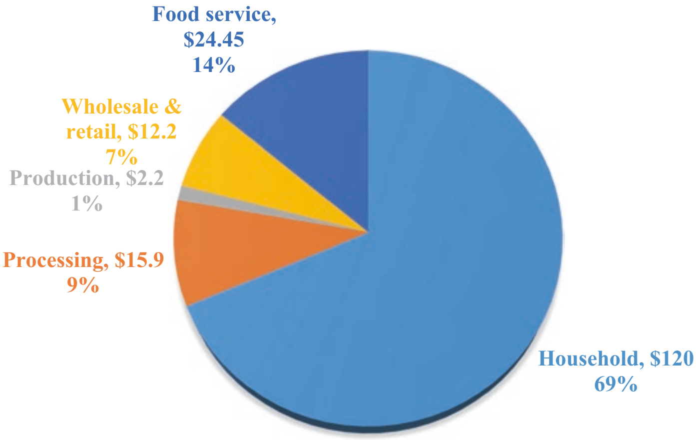

Fig. 2.20 Costs associated with food waste by sector (in billions of dollars) (Adapted From [66])

According to the UN Food and Agriculture Organization (FAO), wasted food costs approximately US$680 billion in industrialized countries and US$310 billion in developing countries. In addition, foods on America's table costs around 10% of America's total energy budget, 50% of America's land, and about 80% of the country's freshwater, while 40% of the US food is wasted [64]. This wasted food is estimated to be about 20 pounds of food per person per month having an economic value of $161 billion [65].

In the EU countries, about 88 million tons of food is wasted annually having a value of about 175 billion dollars [66]. While the total amount of food produced in the EU is around 865 kg/person, about 173 kg of food/person is wasted, which is about 20% of the total food produced. Cost of wasted edible food from different sectors is shown in Fig. 2.20 in billions of US dollar [66].

A mitigation of food waste can save a huge amount of money. It has been found that about 81% of food waste is avoidable. The reasons, amount, and cost of avoidable wasted food around the world are shown in Fig. 2.21.

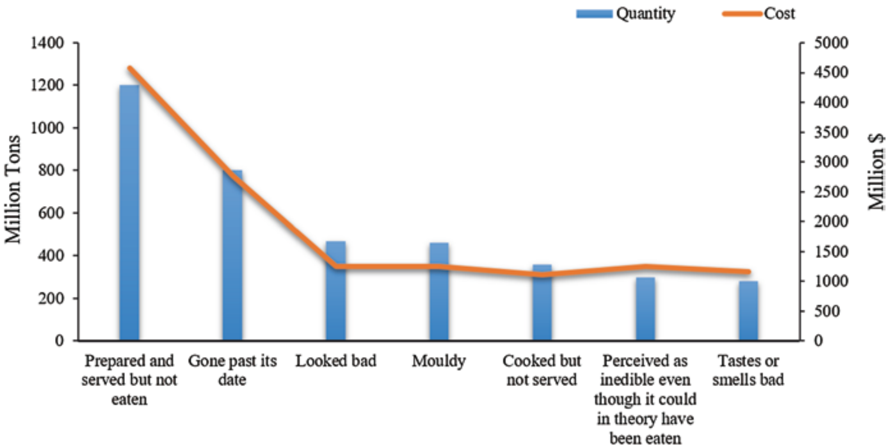

Fig. 2.21 Avoidable food waste [67]

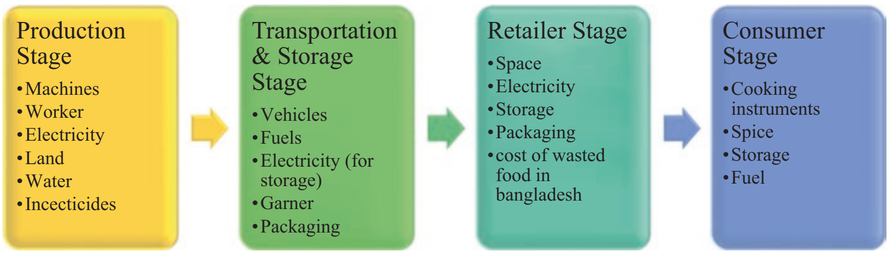

Fig. 2.22 Economic consequences in different stages of food production

Figure 2.22 shows the use of energy and money in different stages of food production [68]. All these sectors cost a large amount of money, energy, and environmental resources like water, and soil.

Several factors cause food waste throughout the food chain in both developing and developed countries. Most of the reasons behind food waste can be avoidable with taking some initiatives.

In the next chapter, existing food preservation techniques available in developing countries have been discussed extensively.

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Chapter 3
A Brief History of Food Preservation

Abstract When people have surplus foods and predict potential food insecurity in the future, food preservation needs to be adapted. From early history, humans felt the necessity of food storage and preservation. Human's inquest mind has innovated and discovered different food preservation systems throughout history. Most of the preservation techniques practiced by the early humans were based on daily experiences. Utilization of natural energy including solar, biomass, and natural phenomena such as evaporation cooling, spontaneous reactions like fermentation are some of the common features of these food preservation techniques. Many traditional food preservation techniques in developing countries still follow this approach extensively. However, a wide variation prevails in each preservation technique in different regions of the globe. This chapter attempts to present a brief on the history of some selected food preservation techniques.

Food is the very basic necessity of human being. In the prehistoric time, human being rarely needed to preserve food as there was no excess food remained after consumption on a daily basis. However, people felt the necessity of storage and preservation of food since an unknown period when there was a surplus of food. The storage made the survival easier during a shortage of fresh food. In addition, the food preservation release people from constantly searching for food. Most of the established food preservation started accidentally or by trial and error basis. Later on, the processes were matured with the experience and were passed down from generation to generation. In addition, most of the preservation methods have been practiced for ages, and the innovation of those may be dated back to prehistory.

For these prehistoric people, sun and open fire were the primary means of preserving their foods. In areas with snow and ice, people started refrigeration of foods with these natural means in ancient time. No remarkable known improvement in food preservation was made for thousands of years. The reasons were varied and complicated across the globe.

It is worthy to mention that the real root of the innovation could not be found in most of the cases due to a set of constraint in preserving the first application of the

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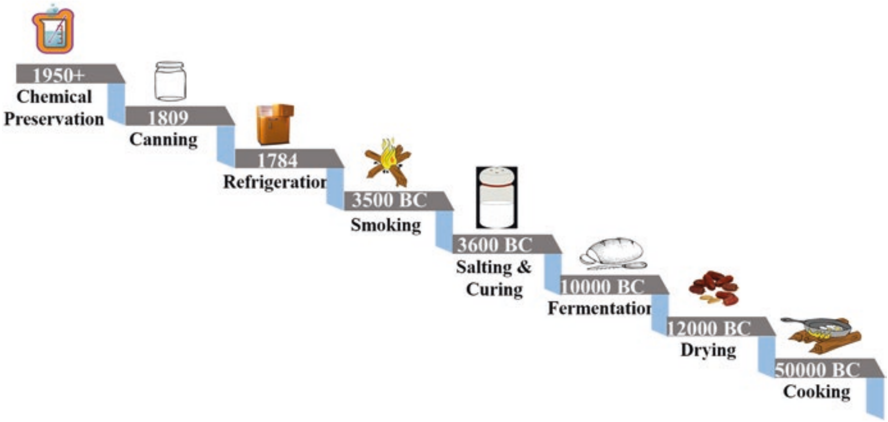

Fig. 3.1 History of food preservation techniques

food preservation. Techniques of food preservation system in the prehistoric ages, when there was no organized form of writing before 4000 BC approximately, are missing in history in most of the cases. As the history of food preservation techniques is very broad and long, history of a couple of selected traditional food preservation techniques is discussed very briefly in this chapter, and summary of the history of all the selected food preservation techniques is presented in Fig. 3.1.

1 Cooking

Cooking may be the oldest food processing and preservation techniques accommodated by human beings. Cooking basically kills different microorganisms including bacteria and let food retain its edibility for an extended time. Cooking can be dated back to the time when human started learning how to control fire. There is evidence that earlier people dated before 500,000 BC started cooking meat and gradually started cooking other types of food.

Cooking techniques expanded extensively with the invention of pottery for boiling water. Then people not only cooked with direct fire but also the heat of boiling water. Therefore, most of the cooking practiced nowadays use heat from boiling water rather from direct flame. Cooking can be categorized as frying, roasting, boiling, steaming, and baking based on the method of heating the food. However, it can be hypothesized that the early form of cooking was roasting in the fire. Roasting was the only cooking technique until the Aurignacian people of France dated back to 30,000 started steaming food with wrapping in leaves and placing upon the fire. Egyptian painting documents show frying, boiling, and broiling were the practiced cooking techniques along with roasting dated back to 4000 BC [1]. Baking came with the invention of oven dated back 6500 years ago in Egypt. However, the diversification in cooking happened during the Renaissance period throughout the globe.

As there are millions of different types of cooking, they are beyond the scope of discussion here in this book. However, early human beings started attaining more nutrition from foods after cooking the raw meats and fishes. In other words, cooking increase the nutrient-retrieving efficiency, and humans adapted it in their life. Nowadays cooking is not practiced as a long-term preservation technique, rather it becomes the means of easy digestion of food and enhancing the taste.

2 Smoking

Alongside cooking using wood, smoking may be an accidental discovery of early human. Most probably, the observation of prolonged shelf life of certain smoke enclosed food including meat and fish triggered the concept of smoking food preservation techniques. Smoking preservation technique may be as old as the advent of cooking as it is also associated with fire. Smoking is a very primitive technique of food preservation, and its origin dates back to prehistory [2].

As far back as 3500 BC, Sumerians smoked their fishes. In Europe, the meat of the slaughtered animals was often smoked for preservation during the Medieval period. Many smokehouses were dedicated to smoking and storing. Nomadic Native Americans were the first people who successfully smoked salmon for month's long preservation. Researchers found that strange kind of centers near Lake Biskupin in Poland for mass production of smoked fish which may be dated back to around the ninth century [3].

Due to an availability of other effective food preservation system, smoking is not practiced as a preservation system anymore. However, smoking is practiced and very popular because of the unique flavor it produces.

3 Drying

At the very beginning of the human history, it may be observed that dried food possesses extended shelf life due to an absence of water, where the harmful bacteria cannot grow properly. Drying can be treated as one of the natural preservation systems as drying involves removal of water from food. In order to reach equilibrium, the atmosphere takes away extra water from foods with higher moisture content. Therefore, drying can happen to some extent in case of keeping food even in open space. Whereas, people in high humid areas such as Eastern countries started practising human-made food drying systems.

In the literature, it is found that people of the Middle East and Oriental culture profoundly used to practice drying of food especially fish and meats as early as 12,000 BC [3–5]. In those days, sun drying was the only option as mentioned in history books. Whereas, Roman people were fond of dried fruit [6, 7]. Therefore, both animal and plant-based foods were dried from very early ages.

During the Middle Ages, people in the areas where sunlight was not strong enough to dry foods started using fire to develop heat in order to dry food in "still house." Sometimes, drying was associated with smoking due to lack of techniques in separating unwanted smoke developed from the fire. During the Iron Age, Northern European people rigorously practiced drying of meats. Alongside the natural foods, human started drying the processed food. For instance, Arab and Italian people dated back to the eleventh century started preserving pasta by drying.

At some unspecific point, human incorporated different mechanical techniques to hasten and improve the drying process [3]. For instance, the people of the Middle East combined macerating, boiling, and leaving apricots on board to dry. By the year 1795 in France, the first dehydrator was developed for drying fruits and vegetables.

4 Salting

Salting has pretty much known longer history than most of the traditional food preservation systems. Even salting has been utilized as the primary preservation method of meat as far back as historical records. Sumerians used to preserve all sorts of food including fish, fats, meat, barley, and wheat in around 3000 BC [8]. During the Iron Age, people of Northern Europe and Roman would preserve food using salt [9]. Ancient Mesoamerican people used to preserve food with salt. People in various parts of the world from a very early age would practice salting in food preservation. Even some of the province such as Newfoundland was colonized due to salting of fish.

In brief, people generally used salt to preserve fish and meats from the availability of salt and its nature of desiccant-like materials. Moreover, very simple and straightforward nature of the salting process is involved which makes it prevailing throughout the history around the globe.

5 Fermentation

Unlike other preservation techniques, natural chemical reaction or active participation of microorganisms such as yeast and bacteria in spoiling raw food is associated with the fermentation process. However, the spoilage process produces new and better notorious food than the raw ones. The use of yeast in bread is one of the examples of fermentation. It is thought that the discovery of fermentation happened accidentally or by trial and error basis [10]. For instance, alcohol may be produced accidentally after some barley was left in the rain.

Both plant- and animal-based foods have been fermented for thousands of years. It is documented that fermentation was discovered dates back to 10,000 BC. Probably, fermented fruits were used to be eaten first among other fermented foods [10]. For instance, Littoral Foragers dated back to 8000 BC would ferment vegetables [11]. During the dynasty of the Pharaoh Era of 4000 BC, it is reported that Egyptian people fermented meat and dairy on a regular basis [12].

Moreover, prior to better use of vinegar, people preserve different types of foods by fermentation instead of pickling as practiced for those foods nowadays.

6 Pickling

The word picklingmay come from the Dutch word "pekel" or Germany "pokel" meaning brine or salt. Anyway, pickles of vegetables such as cucumber have been done in the Tigris valley as far back as 2030 BC [13, 14]. Mesopotamians, Americans, and European started pickling at almost the same period of time. Although vegetables were the primary pickled food, meat and fish were prickled in ancient times. For example, Babylonians and Egyptians pickled fish and meat in ancient time. Even ancient Chinese people pickled eggs in vinegar brines.

Pickling was first introduced in America around the sixteenth century after arriving new foods from other parts of the worlds. The invention of paraffin wax as a seal and Mason jar in the nineteenth century significantly increased the pickling preservation all around the world.

Throughout the history, pickling was not only treated as a preservation technique but also a method of taste enhancement. This nation can be manifested by its huge fan including Julius Cesar, Christopher Columbus, and Napoleon Bonaparte. Similar to smoking, pickling is not used merely as a preservation method rather as a flavor-enhancing technique.

7 Jamming

The word jam may be derived from the verb "to jam = tightly pressed" as the processed food is pressed tightly in a container or jar. It has a very old history as the other preservation method manifested. When people saw that sweetener like honey and date syrup have the same ability to hinder microbial growth as salt does, jamming-type food preservation techniques were started.

The practice of jamming substantially increases with the innovation of sugar. Prior to the innovation of sugar, people use honey, and date syrup was used in the jamming process [6].

For example, quince was mixed with honey and packed tightly in ancient Greece. During the same time, Romans cooked quince and honey together to preserve it [6]. As it is thought that sugar was first chemically refined, sugar was produced in India about 2500 years earlier. Then, sugar was spread all over the world in around the seventh century. Therefore, it can be hypothesized that jamming using sugar syrup was developed in Asia. The earliest documentation regarding jamming can be referred to as the "*De Re Coquinaria* (the art of cooking)" which was written around fourth or fifth centuries BCE. The book is imprinted in Latin in 1498 just after its rediscovery. Mass scale jam of fruit production was not possible before the discovery of pasteurization and jar in the eighteenth century [15].

Unlike other preservation systems, fruit jams were used as medicine in different parts of the world. Nowadays, jam and jelly are mainly produced primarily as a portion of tasty food. This is no more than the main option of food preservation system in many parts of the world.

8 Packaging

Packaging is required to prevent food from coming into contact with the microorganism, oxygen, and other contaminants. Packaging mimics asepsis developed in every plant- and animal-based food materials. In nature, covering is a privilege in every food, for example, fat or skins in animals, the shells of eggs, and peel of fruits. In most of the cases, covering of foods can inhibit microorganisms. It can be thought that packaging has been practiced even by the ancient people with different materials such as grass, seeds, leaves, and leather. Along with these, used empty skin of gourds and hollowed out logs were probably used as packaging system. Packaging was required not only for food preservation but also for food transportation for the ancient people as they traveled a lot for foods.

The innovation of glass and ceramics advanced the packaging system for the early population. However, the recently used flexible packaging which is associated with plastic is innovated several hundred years ago [16]. However, Chinese people innovated paper from sheets of the tree to wrap food dating back to the first or second century BC. Since then, paper was the most used flexible food packaging prior to the innovation of plastic.

On the other hand, hard or rigid packaging has a longer history than the flexible ones. Wood, glass, and pots were discovered earlier than flexible packaging materials. Glass has been widely used for food preservation dates to 3500 BC in Egypt. Glass probably discovered as the offshoot of pottery. It is documented that cups and bowls were first made from glass in molds approximately 1200 BC. However, clear glass was discovered in the third century AD. Further details of early packaging materials can be referred to the work of Risch [17]. Sealed top or screw-top jar was innovated in the 1900s [17]. Glass is popular as packaging due to its diverse advantages including low cost, easy to manufacture, visibility, and inert nature to most substance. Notable advances in packaging systems in the twentieth century upon the innovation of aluminum cans and foil and polyethylene containers.

9 Refrigeration and Freezing

Refrigeration and freezing are the most common prevailed all over the world. Refrigeration can be defined as the process of maintaining a lower temperature of an enclosure or a system than the surrounding. This effect can be achieved through both natural and artificial ways. Early people use snow and ice to maintain refrigeration effect. Early people of North America also used to preserve food in underwater storage system attaining benefits from cold water [9]. The Iron Age people of Northern Europe practiced refrigeration of meat. Ancient people also store food in cold underwater and wells. Even the depth of cave used by the people of Paleolithic times allows cool temperature that is favorable of storage of foods. Romans and Greece people placed snow into food storage pits and insulated using grass and branches of trees.

Utilization of snow and ice in insulated cellars was first practiced in China in the 1100 BC. In addition to this, the concept of evaporation cooling was widely practiced in Egypt around 2500 years ago. Perishable products such as fish and meat were placed in caves and surrounded by ice in different parts of the world. First artificial method of lowering water temperature adding chemicals like sodium nitrate was practice in 155 AD.

Ice was even transported from a distant place for the cooling and refrigeration purposes in early sixteenth century. For example, ice was brought from the mountains to India during the Mughal Emperor in the sixteenth century [18]. By the year 1806, Fredric Tudor started trading ice cut from the Hudson River and exporting it to various countries.

Although natural refrigeration technique has been practiced from prehistoric time, the mechanical refrigeration was not properly developed in the 1950s [19–21]. However, the history of refrigeration and freezing is presented in Fig. 3.2.

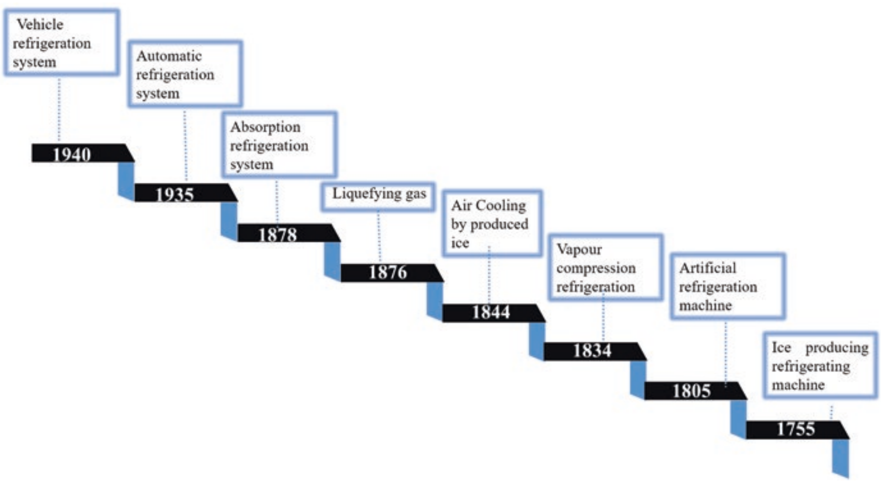

Fig. 3.2 History of refrigeration and freezing [19–21]

10 Food Storage

Alongside different preservation system, food storage plays a vital role in the human history. The innovation of effective food storage system advanced the agriculture and human civilization. The term “food storage” can be defined as the place where food is kept in mass quantity for ensuring food safety in an extended time. Early human store food in the cave as it was in a relatively favored condition than open places. However, the systemic food storage system or granaries were first developed in the early Neolithic period. Archaeologist found grain storage system in Jordan dated back 9500 BC [22]. Details of the system emerged the technical accuracy regarding moisture reduction, the passage of air flow, and prevention of rodent. Moreover, during Prophet Yusuf (peace be upon Him), the people of Egypt store huge amount of grains for several years.

11 Controlled Packaging

Controlled packaging or modified atmospheres packaging (MAP) is an advanced packaging or storage that consider not only prevention of microbial but also slowing natural ripening process of food materials. The concept of the MAP was used date back over 2000 years as shown in Fig. 3.2. The process is mainly used for extending shelf life in a modified atmosphere in almost absence of oxygen. The first established controlled atmosphere storage system was built in the United States in the 1860s. Further remarkable development has been enlisted in Fig. 3.3.

Commercial application of both animal- and plant-based food materials was recorded as early as the 1930s. Nowadays it is practiced to such an extent that only the United Kingdom sold 2.8 MAP pack of food in 1998 [24].

12 Canning

Canning is relatively younger in comparison with other food preservation systems. The process was pioneered by Nicolas Appert in the early eighteenth century. This process was established after the close observation of the application of heat in sealed glass bottle-preserved foods and its great quality retention. It emerged just after the invention of metal cans. Canned seafood and fish was first contributed to the United States in 1815. Fish like tuna, shad, and alewives were canned firstly early in the twentieth century [25].

It is probable that tuna, alewives, and shad were not canned until early in the twentieth century. Canning controlled heating of cans and nowadays provides an improvement in the texture and nutritional value of the canned food due to the lower thermal processing time [26].

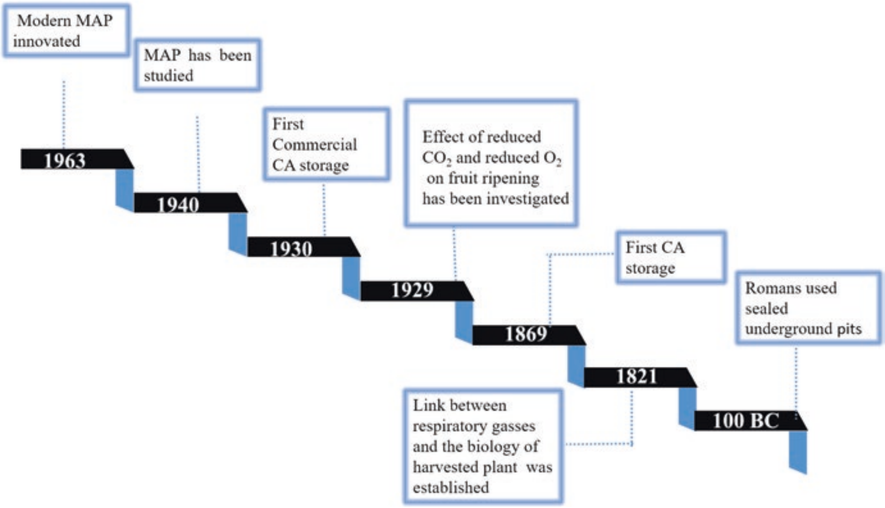

Fig. 3.3 Important conceptual and technological advances in CA and MAP [23]

From the above discussion, it is clear that most of the preservation techniques have an enriching historical background. It is quite impossible to trace back the first incident time of a particular food preservation techniques. Therefore, the common sayings regarding individual preservation techniques have been mentioned in different sources of food history. Whatever the part of the history witnessed the first incident, the contemporary population must show their gratitude to those inquisitive people.

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Chapter 4
Food Preservation Techniques in Developing Countries

Abstract Proper food preservation must be executed in order to overcome the food waste problem of developing countries. There is a wide range of food preservation techniques prevailing across the globe nowadays. Individual techniques put importance on one or more key factors of food waste including microbial proliferation, enzymatic reaction, chemical reaction, as well as physical damage. Consequently, the required process conditions vary significantly through the preservation techniques. Several types of preservation techniques are performed on the basis of some common physical phenomena including heat transfer, moisture removal, and prevention of enzymatic and chemical reaction. A wide range of common food preservation techniques has been discussed in this chapter.

Food spoilage occurs mainly due to microbial, chemical, and enzymatic reactions and physical factors. Throughout the food chain, food is susceptible to attack, growth, and reproduction of microorganisms. Similarly, unwanted chemical and enzymatic reactions that deteriorate food quality can take place in any stage of the food process [1]. Determination of its severity in terms of quality in food depends on both the cause of spoilage and its intensity as represented in Fig. 4.1 [2].

Food preservation can be done by controlling the pathogen population and preventing or delaying unfavorable reactions. Apart from these, some other factors such as measures to prevent mechanical damage should also be considered as a part of food preservation technique.

On the basis of the fundamental principles as shown in Fig. 4.2, there are many ways to preserve food including drying, canning, salting, freezing, pickling, sugaring, airtight storage, irradiation, and vacuum packaging. In some particular preservation cases, pre- and/or post-processing may be required depending on the product and the process type. There are several options available for pretreatment such as osmotic dehydration, blanching, and soaking, whereas coating, blending, and packaging techniques are used for post-processing.

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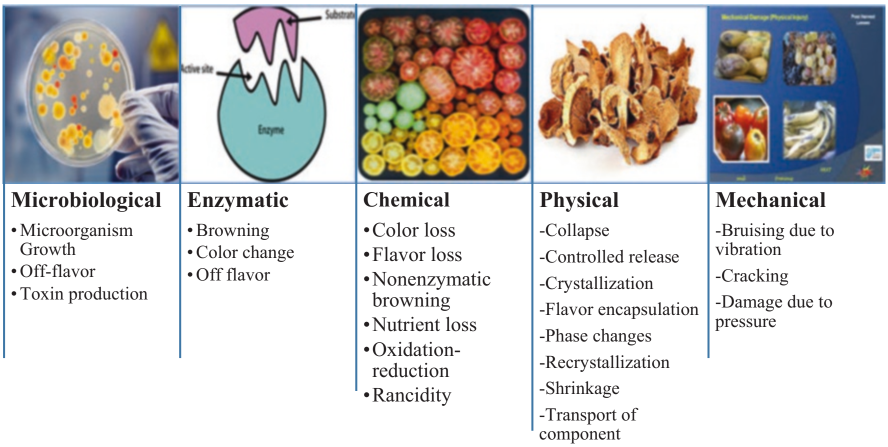


Fig. 4.1 Major quality loss mechanisms in food

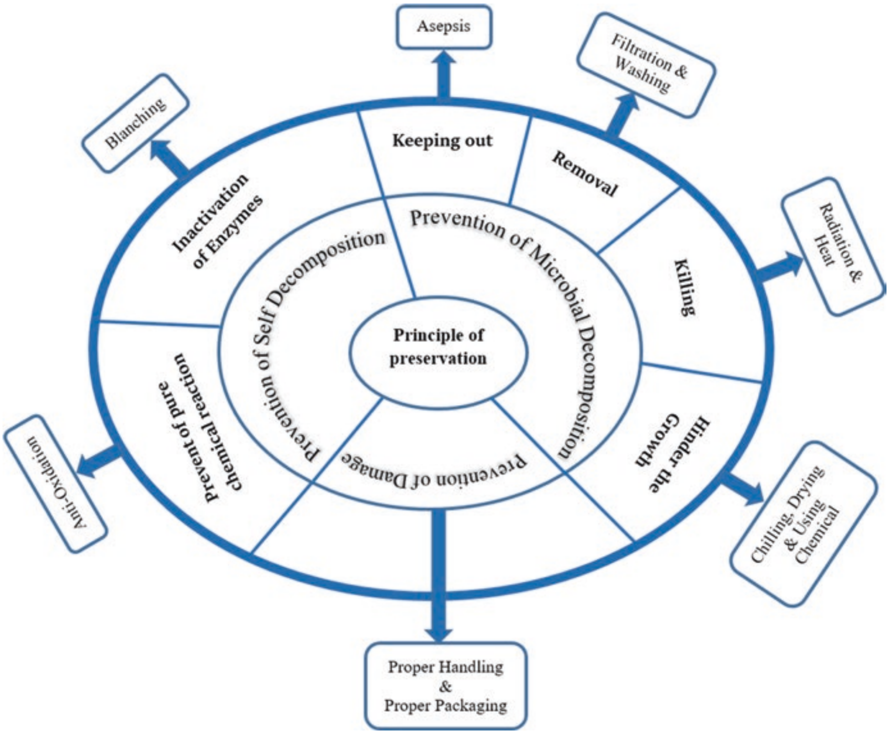


Fig. 4.2 Major principle of food preservation

Although most of the preservation techniques have been carried out for a long time all over the globe, continuous developments are in progress to improve those preservation techniques. In developed countries, most of the processes are equipped with modern technology. Although in developing countries there are many preservation techniques in practice, they are very old-fashioned and far from a scientific basis. Generally, the following characteristics are common in most of the food preservation techniques in developing countries.

- Lack of scientific basis
- Low initial, maintenance, and operating cost
- Easy in fabrication with local available materials
- Free from complicated electronic or mechanical system
- Easy to maintain the system
- Energy comes naturally

Most of the developing countries still rely on the traditional food preservation techniques including open sun drying, salting, smoking, and evaporative cooling. For example, more than 70% of food in Nigeria is processed traditionally [3].

To maintain the scope of this book, the food preservation techniques presented in this chapter have been confined to those which are very common and widely practiced in developing countries across the globe.

1 Pretreatment

1.1 Cooking

Although Spices and herbs are traditionally added to meat products, mostly as flavoring and aromatizing agents, however, it is currently also recognized as one of the contributors to the improvement of food safety and keeping its quality [4–12].

Besides this, cooking also develops the flavor of the food; for example, the flavor of uncooked flour or sour apples is not very pleasurable, but while the flour is transformed into bread and the apples stewed with sugar, their flavors are greatly upgraded [4]. Cooking might correspondingly increase the attractiveness of food. There are different ways to accomplish the process of cooking depending on the methods of heating the food as presented in Fig. 4.3 [13].

1.2 Blanching

Blanching is the pretreatment of different types of food processing systems including drying, canning, and freezing. Blanching generally inactivates enzymes, maintains color and freshness, and stabilizes nutritional quality and texture. In addition,

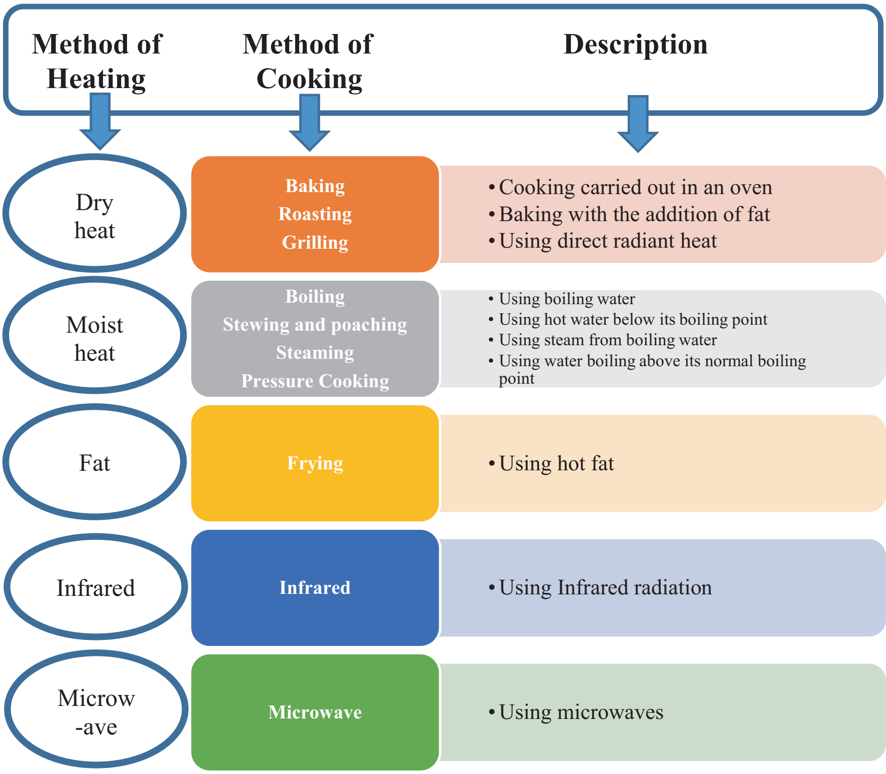


Fig. 4.3 Different processes of cooking method

blanching destroys microorganism to an appreciable extent and expels intercellular air. However, improper blanching may deteriorate aroma and some soluble nutrition. For example, foodstuffs such as onions, leeks, and peppers lose substantial amount of flavor and color during blanching. The overall effect on different quality attributes of blanching is shown in Fig. 4.4 [14–17].

Removal of intercellular air during blanching plays a critical role in drying, freezing, and canning process. For instance, the trapped air and metabolic gases are replaced by water that forms a semicontinuous water phase, which favors further uniform crystal development during freezing. In addition, the removal of gas is one of the key advantages of blanching since before canning it permits easier can fill, decreases strain on can for the period of heating, and diminishes can corrosion [18].

Fruits are typically not blanched or blanched in mild (low-temperature) environments preceding to freezing since blanching creates adverse texture modifications. Blanching is sometimes done with fruits and vegetables before drying [19]. To chill the blanched fruits and vegetables, cold water is sprayed or sometimes conveying them to a flume of cold water that often serves to transport them to the next part of the process. Blanching can be done in several ways as displayed in Fig. 4.5.

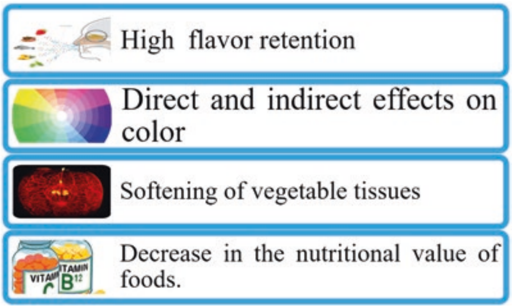
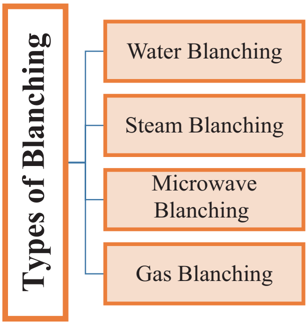


Fig. 4.4 Overall effect on different quality attributes of blanching [14–17]

Fig. 4.5 Types of blanching



Water blanching is accomplished in hot water at temperatures ranging from 70 °C to 100 °C. Nevertheless, combination of low-temperature long-time (LTLT) blanching and high-temperature short-time (HTST) blanching have similarly been considered [19–21]. In general water blanching results in a further even treatment which permits processing at lower temperature. Blanching using hot water is mostly practiced in developing countries as shown in Fig. 4.6 that blanching of chili is being done in traditional oven in Myanmar.

In steam blanchers, the processes are conveyed by a chain or belt conveyor over a chamber where “food-grade” steam at about 100 °C is straightly injected. Generally, the flow rate of steam is controlled, and temperature in the headspace is measured. Steam blanching is typically used for small products and necessitates fewer time than water blanching. The reason behind this is the heat transfer coefficient of condensing steam which is larger than that of hot water [22].

Fig. 4.6 Typical blanching operation in rural area

1.2.1 Microwave Blanching

The study of microwave blanching has started since the 1940s [23]. Microwave blanching requires very short processing time compared to the conventional water or steam blanching. In the earlier time in order to use microwave blanching, batch oven were used, which made it difficult to cool the products. This problem can be overcome by using continuous oven, which is discovered later on. However, maximum studies on microwave blanching have been completed by means of commercially obtainable home microwave ovens.

Current researches have used different produces and upgraded instrumentation such as fiber-optic temperature probes and infrared thermal imaging camere to observe heat penetration. To reduce the heating time, microwave heating has been combined with water blanching [24, 25]. It is found that microwave ovens will reduce the processing time that will result in minimized operating costs and higher-value products.

Flue gases along with steam is used in gas blanching to increase humidity as well as prevent product dehydration. This type of blanching is really advantageous to reducing waste production compared to conventional blanching but often results in product weight loss. This method is not presently used in the industry and therefore requires advance research [18].

Apart from the hot water blanching, other types of blanching are not very common in developing countries due to the requirement of advanced technology to adopt the blanching in a right way.

2 Canning

In developing countries, people seldom consume canned foods. It may be due to high cost that is beyond the affordability of the consumer. This high cost of canning is the consequence of huge energy and freshwater requirement. However, enormous amount of canned food of different types are exported from developing countries to their developed counterparts as shown in Fig. 4.7. For instance, European countries import almost 25% of canned fruits and vegetables from developing countries. Different types of canned fish, vegetables, and fruits contribute a substantial amount of foreign money for low-income countries.

Canning is a type of food preservation that is accomplished with a combination of processes including heating and cooling. Canning prevents microorganism growth and deactivates enzymes. The basic steps involved in canning are represented in Fig. 4.8.

Initially, the raw materials must be processed appropriately as some foods including fishes comprise dangerous microorganism such as *Clostridium botulinum*. In canning, all the foodstuffs must not be heated in the same manner. The extent of time and the temperature required rely on several factors, which is revealed in Fig. 4.9 [26].

However, the best quality is attained by ensuring the heating conditions and using fresh, healthy products. The amount of primary microorganisms and the internal water content is high in fish and meat. However, the pH is almost neutral in those

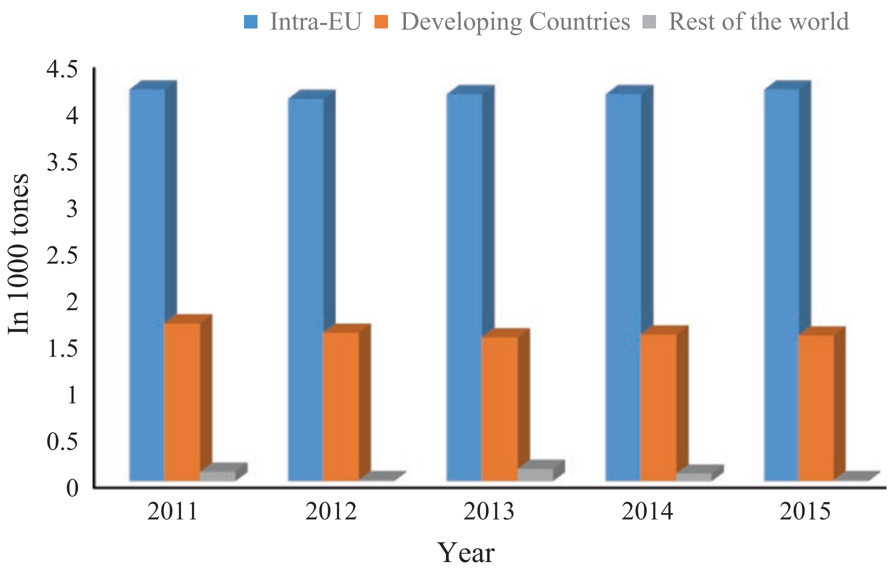


Fig. 4.7 Different types of exported canned food from developing countries to their developed counterparts. Adapted from [27]

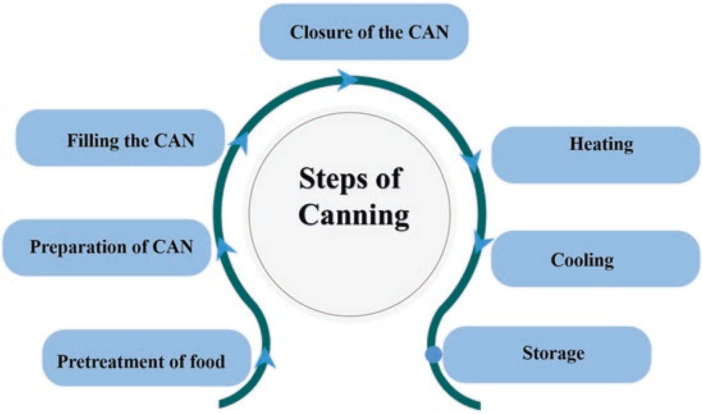


Fig. 4.8 Steps in canning of fish

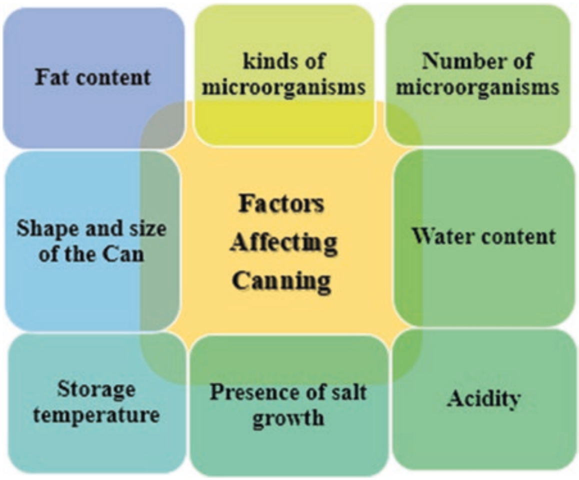


Fig. 4.9 Factors affecting the required temperature and time for canning

foods. Eventually, elementing all existing microorganisms and obtaining a harmless product is really a challenging task. However, persistent heating in a pressure sterilizer in temperatures which can reach higher than 100 °C can be a harmless option. As the canning of fish and meat requires huge amount of energy, freshwater, and investment in equipment, typically it is only practiced at a small-scale industrial level [26].

After heating protein-rich foods, the commodities are sealed hermetically in cans or jars. Plant-based food materials do not require heating prior to sealing in cans. In order to prevent growth of microorganisms, vinegar, acetic acid, or even oil is used in the can; eventually, canned foodstuffs may be stored for an extended time without refrigeration.

3 Low-Temperature Techniques

Microbial growth is significantly affected by temperature. Below the lower optimum temperature, microbial encounters hurdle growth and propagation. Low temperatures can abate enzymatic action, chemical reaction, and growth of microorganisms in foods. Even a low enough temperature can completely stop the growth of microorganisms. In addition, at lower temperature, the chemical reaction is slowed down, and enzyme action is also reduced. Apart from these, the low-temperature method provides the following benefits for foods:

- Less perishability due to reduced respiration
- Less shriveling and water loss
- Less ripening due to reduced ethylene actions
- Reduced browning reaction result in less color changes
- More nutrient retention

There are many ways to achieve low temperature including chilling and freezing as shown in Fig. 4.10.

Although all of the listed techniques are associated with low temperature, the temperature and cooling rate are not identical. Consequently, the change in structural, nutritional, and energy consumption varies between techniques.

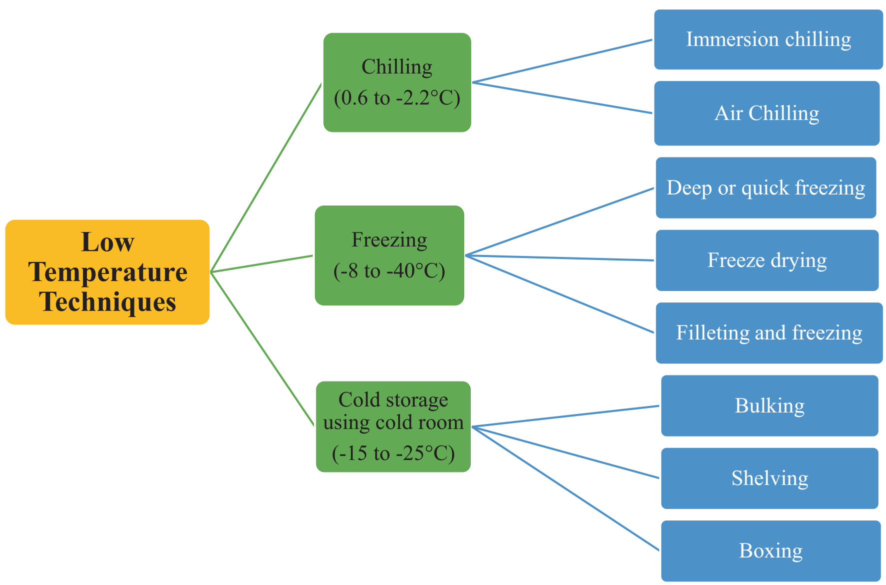


Fig. 4.10 Types of low-temperature techniques

3.1 Cold Storage Using Cold Room

The temperature in cold storage is maintained not far above freezing point. The cooling in this process is attained by ice or mechanical refrigerator. Although cold storage can be used for most of the types of food materials, fish is mainly preserved in cold storage in the developing countries. However, we will further discuss on the fish preservation to compare the procedure of different techniques associated with cold room including boxing and bulking.

3.1.1 Boxing

Boxing is accomplished by laying fish on a thick ice at the lowermost section of a container followed by alternating layers of ice and fish [28, 29]. The top layer of the box is filled with ice in boxing. There are distinct advantages of boxing fish over bulking and shelving such as the fish might effortlessly be separated into species and sizes; as well as removing fish boxes from fishing vessels. Boxing confers several advantages as shown in Fig. 4.11.

Most of the developing countries adopt the various boxing techniques for short fish preservation. Different types of boxing are used that are made of foam, paper, and plastic as shown in Fig. 4.12. Poor quality of boxing containers may result in quick melting of ice.

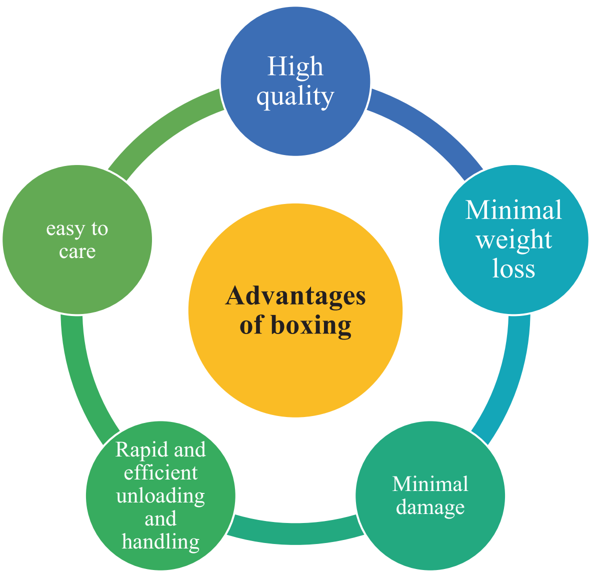


Fig. 4.11 Advantages of proper boxing

Fig. 4.12 Practical pictorial view of boxing

3.1.2 Bulking

This is laying fish on a bed of thick ice and placing alternate layers of ice and fish at a fish-to-ice ratio of 1:1 or 1:2 up to a total height of 1 meter. However, bulking storage may cause damage and shrinkage of fish for the pressure developed due to layer of fishes [30]. A practical pictorial view of bulking typically used in developing countries is represented in Fig. 4.13.

3.2 Freezing

For preserving food, freezing is one of the most ancient and extensive approaches. Food that is preserved by freezing retains higher taste, texture, and nutritional value in comparison with any other techniques. Freezing is a low-temperature technique in which microorganisms cannot reproduce, chemical reactions are reduced, and cellular metabolic reactions are hindered [31].

Freezing preservation maintains the excellence of food products over an extensive period of time. As a technique of long-standing preservation for food materials, freezing is usually considered as superior to canning and dehydration [32].

Freezing has been efficaciously engaged for the long-standing preservation of many foods, providing an expressively prolonged shelf life. The process includes dropping the product temperature usually to −18 °C or lower than this [33]. When energy is detached by cooling below freezing temperature, then the physical state of food material is transformed. However, if the temperature is extremely cold, then it

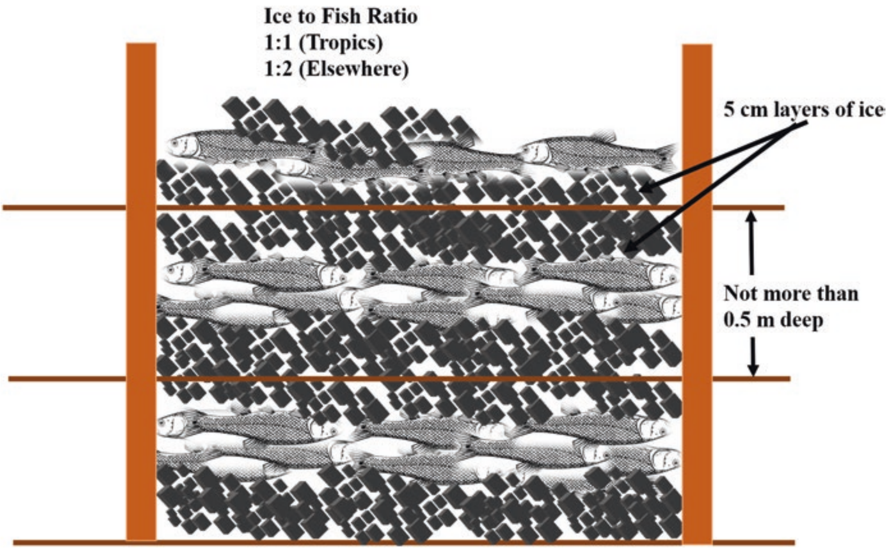


Fig. 4.13 Food preservation by bulking. Adapted from [30]

modestly hinders the advancement of microorganisms and decelerates the chemical changes that affect the attributes for which food spoils [34].

Despite the excellent performance of preservation along with ensuring the high quality, frozen food has not commonly prevailed in developing countries. However, domestic-level freezer is common in the affluent and higher middle-class people in developing countries. In general, people of developing countries are not fond of frozen foods. Eventually, it is one of the least industrialized food preservation techniques in perspective of the developing countries.

Food preservation by freezing is becoming popular in recent times for several types of food commodities including fruits and vegetables. The scenario of implementing freezing techniques is similar in both developed and developing countries. Freezing of fruits and vegetables in small- and medium-scale operations is represented in Fig. 4.14 [35].

However, besides fruits and vegetables, meat and fish are also some of the main foods whose characteristics are retained after the process of freezing [36]. Meat comprises of 50–75% water weight, depending on the species, and the method of freezing transforms the maximum percentage of that water into ice [37]. The phenomenon of meat freezing is very quick, and nearly 75% of tissue fluid freezes at −5 °C. While the temperature is decreased, the rate of freezing is increased, and around 98% of water freezes at −20 °C. However, widespread crystal formation takes place at −65 °C [36, 38]. Table 4.1 illustrates the storage life of meat at different temperatures [36, 39].

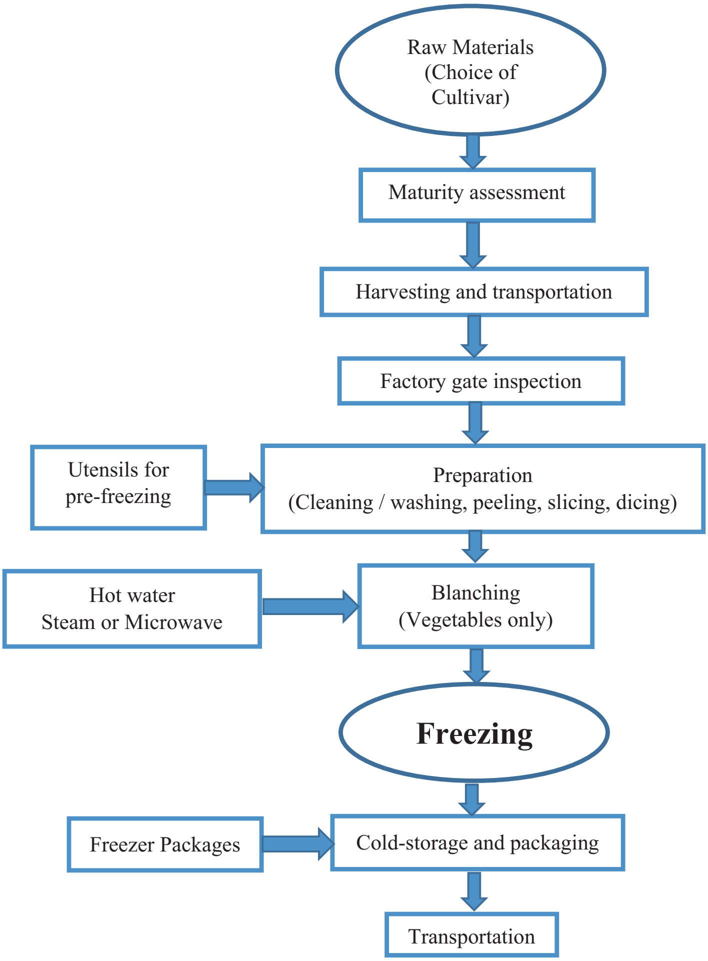


Fig. 4.14 A general flowchart for frozen fruits and vegetables. adapted from [35]

3.3 Chilling

Chilling needs lower temperature than the cold storage and higher than the freezing process. The temperature in chiller is maintained with a range of −1 °C to 4 °C. Lower temperature in chiller can be provided by ice or mechanical refrigerator. Chilling does not cause any hardening of fish due to the relatively low temperature persisting in chilling chamber.

Even though it is an effective technique of preservation of highly perishable and protein-rich foods such as fish and meat, getting ice might be problematic and costly for the people of lower-income countries [40].

A higher rate of cooling is essential to ascertain the good quality and the increased shelf life of chilled product. Chilling is only effective for short-duration preservation,

Table 4.1 Storage life of meat at different temperatures [36, 39]

Product	Temperature (°C)	Storage life
Cooling beef	−1	3–5 weeks
Pork	−1	1–2 weeks
Freezing beef	−18	12 months
	−30	24 months
Ground beef (wrapped)	−18	6 months
	−24	8 months
Beefsteaks (vac. Packed)		18 months
		24 months
Lamb and mutton	−18	16 months
	−24	18 months
Pork	−18	6 months
	−30	15 months
Liver	−18	12 months
	−24	18 months

for example, transportation of landed fish to nearby markets or to canning factories, etc. [36, 41].

There are two types of chilling, namely, immersion chilling and air chilling [36]. In immersion chilling the product is immersed in chilled (0–4 °C) water. On the other hand, in the air chilling, the foodstuffs are misted with water in a room with circulating chilled air [42]. By air chilling food surface temperature is minimized at quicker rate that increases drying rate and diminishes microbial spoilage [43]. Maximum quality attributes such as microbial quality of the food in the air-chilled produce are superior than that of a water-chilled product [44, 45].

3.4 Superchilling

Superchilling is one of the low-temperature preservation systems that maintains lower temperature than freezing temperature. Superchilling is more feasible for certain foods over refrigeration and freezing, which eventually decreases storage and transport costs.

The development of microorganisms is highly influenced by the temperature of the food materials [46–50]. Microbial activity and the growth of most bacteria can be reduced remarkably at superchilling temperatures.

The superchilling method incorporates low temperatures along with transforming of water present in food into ice that makes food water unavailable for the growth of microbial [47–49]. The formed ice will absorb heat from the interior surface, which eventually reaches the equilibrium condition. In superchilling an internal ice reservoir is served to the food products that is why there is no need for

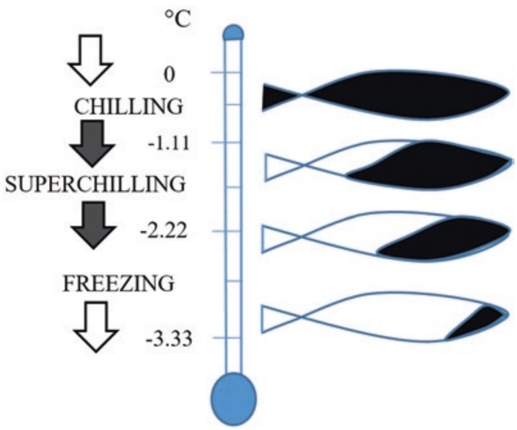


Fig. 4.15 Temperature range of different food storage technologies [51]

external ice around the product during its short-time transportation or storage. As the preliminary freezing points for maximum foods range from −0.5 °C to −2.8 °C, the superchilling temperature is maintained below that [51]. The various temperature ranges of different low-temperature food storage technologies such as chilling, superchilling, and freezing are represented in Fig. 4.15.

3.4.1 Superchilling Technologies

Different types of freezer can be used in the process of supercoiling. The most common types are mechanical freezers, cryogenic freezers, and impingement freezers.

Mechanical freezers use a circulating refrigerant to attain lower temperature and cool food through heat exchanger. Mechanical freezers require greater processing time due to its lower heat transfer coefficients ($h \ll 50\ W/m^2K$). Eventually, inferior quality of product is attained in this superchilling process [52]. Due to its low cost, the superchilling process in developing countries consists of mechanical freezer.

Besides mechanical freezing, cryogenic freezer is used in case of extensively low-temperature requirement. Generally, nitrogen liquid (−196 °C) or carbon dioxide (−78 °C as a solid) is used directly to the foodstuffs to attain pretty lower temperature. Due to the high-temperature gradient between the cryogen and the food product surface, cryogenic freezing is a faster cooling process than conventional air freezing [53].

Despite of having quick freezing rate, cryogenic freezing is a costly option Zhou et al. [52–54]. Moreover, profound alternation of food structure occurs during this freezing technique. Therefore, only the expensive foods can be considered to be frozen in this process. Subsequently, cryogenic freezing is less prevalent in developing countries.

In impingement freezers there are multiple freezing chambers separated in different temperature zones in order to maximize utilization of thermal energy. The required temperature of every zone is automatically controlled. Heat transfer rate is higher in the impingement freezer compared to the conventional freezers [55–58]. The processing time of impingement freezers is lesser than the time necessary in conventional belt tunnel freezers [52]. Furthermore, the freezing times for impingement freezing are alike to that of cryogenic freezing at a markedly lesser operating cost.

In summary, frozen foods in particular fish, meat, and fruits are not popular for consumption in developing countries. However, many developing countries attain foreign share in exporting frozen foods to the developed countries. For example, Vietnam exports *basa* frozen fish fillets to different developed countries including the United States and Australia.

4 Drying

Drying is one of the oldest even ancient food preservation techniques. Therefore, it is still one of the most dominating food preservation techniques, which is practiced in developing countries across the globe.

Accessible water is essential for the growth of microorganisms in food materials. Most of the raw food materials are high in water content and make it susceptible to growth of microorganisms. Drying is basically a water-removing process. Simultaneous heat and mass transfer take place during drying process. In addition to the prevention of microorganisms, drying offers an ease in handling, packaging, shipping, and consumption.

There are many types of drying process available which are basically classified on the basis of heat-supplying strategy. The most widely used drying methods in developing countries are solar drying, sun drying, hot-air drying, and spray drying. Fig. 4.16 represents the different types of drying system that are usually used.

4.1 Sun Drying

Sun drying is a process which is practiced throughout the world where food is exposed to the wind and sunrays. In solar drying process, the direct heat energy that comes from the sun is used to dry food materials. In this process, the foods are spread in a thin layer all over the ground or over the trays as per the indication in Figs. 4.17 and 4.18.

In this process the heat is transferred to the food in two ways: one is by convection process and another by the direct solar radiation process. This increases the inner temperature of the foods and results in evaporation of the water from the food. The surface water generally is removed by the natural airflow.

As his process runs under the ambient pressure condition, higher drying time is required slow. During sun drying, the crop can either be dried or rewetted while the humidity increases with the decreasing ambient temperature [80].

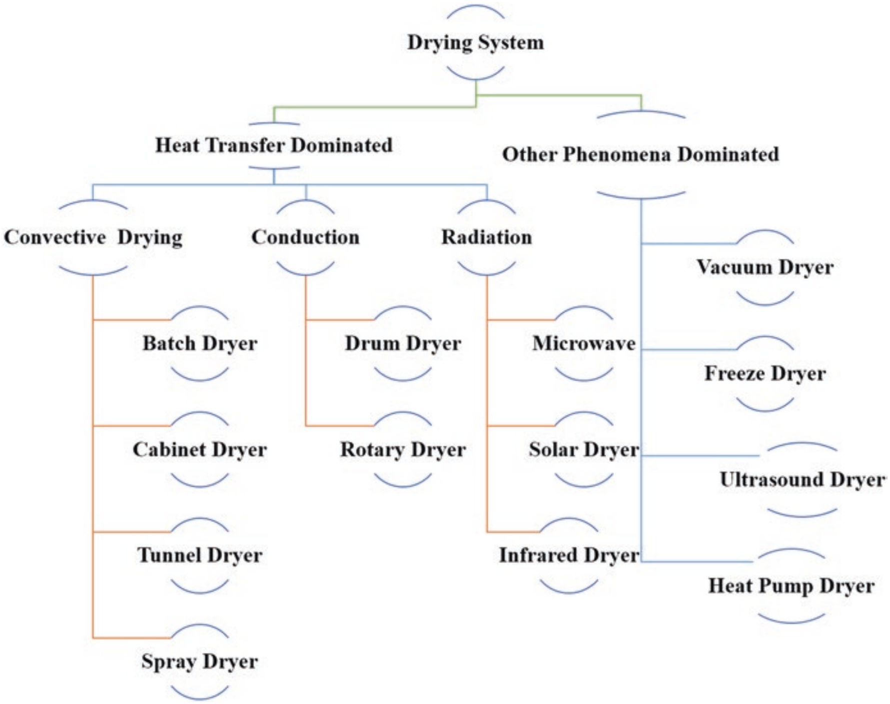
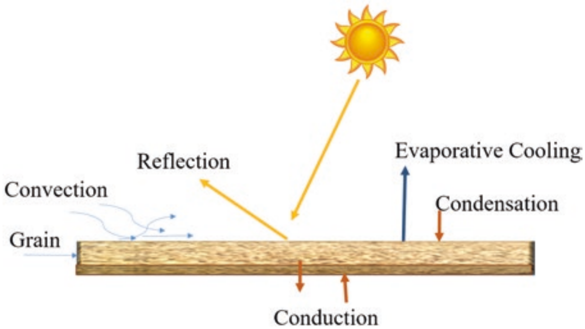


Fig. 4.16 Classification of food drying

Fig. 4.17 Heat transfer during sun drying [80]



Open sun drying is the most prevalent food preservation technique in the developing countries. It is reported that about 95% respondents in a survey in Uganda and 80% of their Nigerian counterparts used sun drying as a method of food preservation [59, 60].

In developing countries, spreading of foods is kept on the roadsides, bare grounds, or rooftops during drying. All sorts of foods including grains, fruits, meat, and fish are dried in open sun drying. Counties in South Africa mainly depend on the open sun drying process for all sorts of food materials including high-moisture-content agro-products such as tomatoes, mangoes, and banana [61].

Fig. 4.18 Sun drying of food

4.2 Spray Drying

Spray drying is less common in developing countries. It is usually used for making powder of certain heat-sensitive product including milk and coffee. The high cost associated with the spray drying is the main hurdle of extensive uses in low-income countries.

In spray drying, the fluid-state feed is converted into a dried particulate form by spraying the feed into a hot drying medium [62]. A spray dryer generally operates on the principle of convection heat and mass transfer.

Spray drying facilitates high evaporation rate due to the increased surface area of the liquid feed drops. Liquid feed flowing in the spray dryer experiences a sequence of conversions before it becomes powder. The modifications are caused by the effect of each of the four stages involved in spray drying, namely, atomization of the feed solution, contact of spray with the hot gas, evaporation of moisture, and particle separation, which is shown in Fig. 4.19.

Atomization is the heart of spray drying and is the first phase conversion process that the liquid feed experiences in the course of spray drying. As the shape, structure, and velocity and size distribution of the droplets along with the particle size and nature of the ultimate product affect drying rate, proper atomization is essential. Then, the droplets pass through hot gas, and this causes quick evaporation of moisture from the surface of all the droplets uniformly.

After evaporation of moisture from the droplets, two stages of separation take place. Powder of the raw liquid is eventually collected after these separation stages.

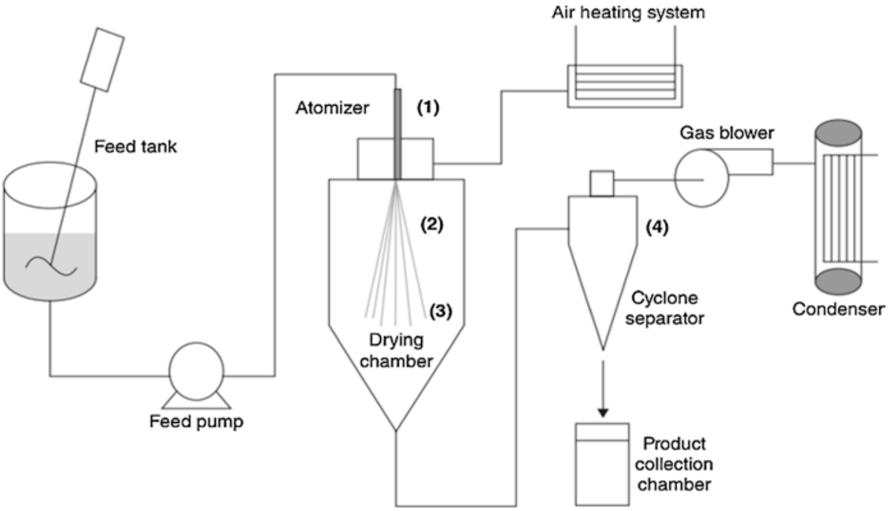


Fig. 4.19 Process steps of spray drying. (1) Atomization. (2) Spray-hot air contact. (3) Evaporation of moisture. (4) Product separation. Adapted from [63]

4.3 Hot-Air Drying

Solar radiation is a great source of heat; however, there is uncertainty of energy availability. For continuous and substantial supply of hot air, electrical or other conventional fuel can be used. When the hot air is produced by using energy source other than the sun, it is known as hot-air convective drying system. The cost of this system depends on the nature of fuel or energy used for heating the air. Hot-air drying is for drying different fruits and vegetables, for example, banana, mango, and pineapple, tea leaves, and herbs such as basil, lemon balm, and bay leaves. In some developing countries, hot-air drying is also used in drying grain, and Fig. 4.20 shows such type of dryer [64].

This type of simple dryer basically contains an axial fan, an electric heater, and a bamboo-mat drying bin. The drying bin is constructed out of two concentric bamboo-mat fabricated cylinders. Sometimes, a waste heat that is carried by the exhaust of coal stove may be integrated as an auxiliary heating system to the dryer promoting the efficiency of drying significantly without any additional cost.

4.4 Solar Drying

Solar drying system is the improved version of sun drying. Generally, food is placed in an enclosed chamber in solar drying system. This enclosed chamber ensures the safety of foods from the outside damage and contaminations caused by birds, insects, dust, and unexpected rainfall.

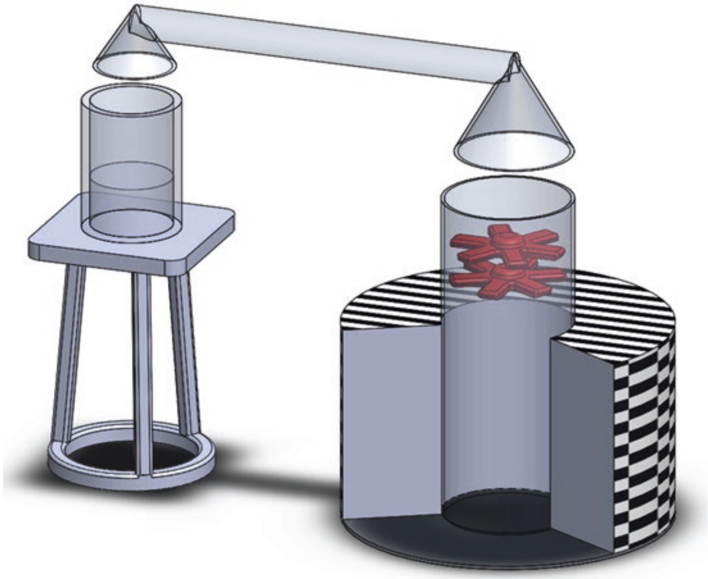


Fig. 4.20 Construction of SRR-1 dryer with coal stove. Adapted from [64, 65]

In the solar drying system shown in Fig. 4.21, the heated airflow is circulated over the product to reduce the moisture content of the body. There are trays inside the dryer where the washed and prepared foods are placed. At the lower part of the solar dryer, there is an air inlet through which the dry air enters into the chamber. The rays from the sun directly enter into the cabinet and stuck there. Then the solar thermal radiation causes increase of the inside temperature. This heat drives the moisture away from the food materials. Eventually, the heated air takes drives moisture away from the food to the atmosphere through the air outlet.

Despite the enormous benefits of solar dryer over sun dryer, farmers rarely use solar system to dry their valuable commodities.

5 Fermentation

In food processing fermentation can be considered as a process, whereby using microorganisms like yeasts or bacteria—under anaerobic conditions—carbohydrates are converted into alcohol or organic acids [67]. The natural sugar existing in the raw foods as well as the added sugar is converted into acid during this period of time. By the action of lactic acid bacteria, flavor, texture, and all the other characteristics are formed. In this way products can be preserved throughout the year [68].

In developing countries, fermentation of food materials is especially used in circumstances where drying of fish is impossible in the absence of the sun and in the

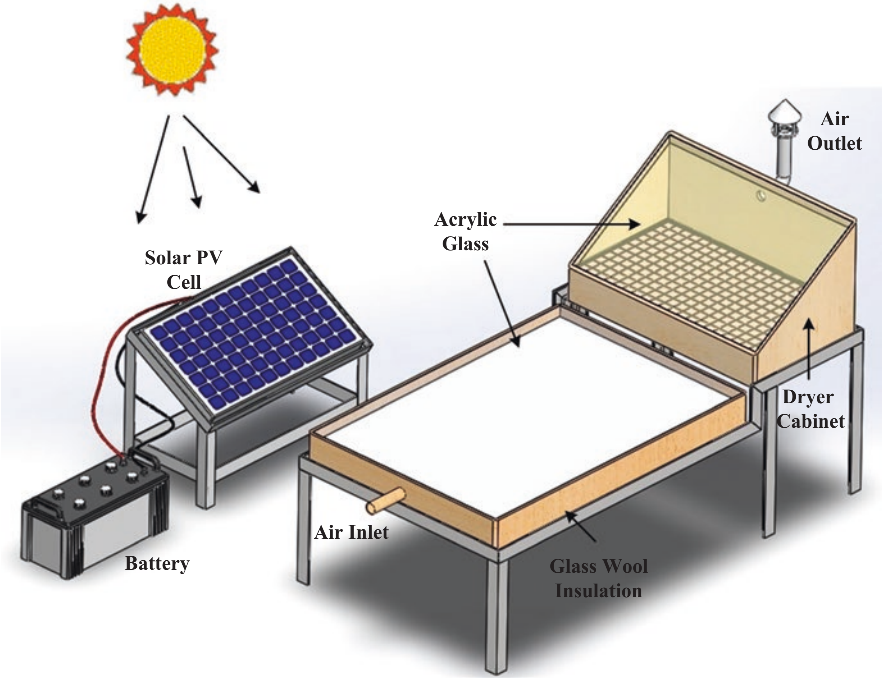


Fig. 4.21 Schematic diagram of a solar dryer [66]

Table 4.2 The benefits of fermentation

Raw materials	Stability	Safety	Nutritive value	Acceptability
Meat	Definite improvement	Usually some improvement	No improvement	Some cases of improvement
Fish	Definite improvement	Usually some improvement	No improvement	Some cases of improvement
Milk	Definite improvement	Usually some improvement	Some cases of improvement	Some cases of improvement
Vegetables	Usually some improvement	Some cases of improvement	No improvement	Some cases of improvement
Fruits	Usually some improvement	No improvement	No improvement	Definite improvement
Legumes	No improvement	Some cases of improvement	Some cases of improvement	Usually some improvement
Cereals	No improvement	No improvement	Some cases of improvement	Usually some improvement

Definite improvement	(blue)	**Usually some improvement**	(orange)	**Some cases of improvement**	(yellow)	**No improvement**	(green)

wet climate. For preserving perishable food materials, fermentation can be a sustainable and an energy-efficient option that offers several benefits as shown in Table 4.2 [68].

From Table 4.2, the benefits of fermentation for different foods such as meat, fish, vegetables, cereals, and fruits vary differently. Here the effect of fermentation is shown in terms of stability, safety, nutritive value, and acceptability. A definite improvement in stability of meat, fish, and milk can be attained by fermentation process.

It has been projected that almost 13 million infants and children under 5 years of age die annually in the tropical areas of the world. The most common and negative reason behind this is the diarrheal diseases. Foods prepared under unhygienic conditions and frequently being heavily contaminated with pathogenic organisms cause diarrheal, nutrient malabsorption, and malnutrition. In every food, there is huge amount of different microorganisms, which varies depending on the several factors. However, fermented meat, fish, dairy, cereal products, and vegetables are not regarded as a vital source of microbial food poisoning [69]. Eventually, fermentation becomes one of the cheapest and the safest food preservation techniques for the people of developing countries. For this reason, greater details on the fermentation process practiced in developing countries need to be discussed.

Fermentations can be categorized broadly as solid state or submerged cultures as shown in Fig. 4.22. In solid-state fermentation, the microorganisms grow on moist solid in the absence of free water. However, insignificant amount of capillary water may present. Mushroom cultivation, bread making, processing of cocoa, and manufacturing of some traditional foods, e.g., miso (soy paste), soy sauce, sake, and soybean cake, are some common examples of solid-state fermentation.

On the other hand, dissolved substrate including sugar solution and solid substrate that is suspended in a large amount of water to form slurry are usually used in submerged fermentation process. Pickling vegetable producing wine alcohol, yoghurt, and soy sauce is the very common example of submerged fermentation in developing countries. Both types of fermentation can be carried out in the presence or absence of oxygen.

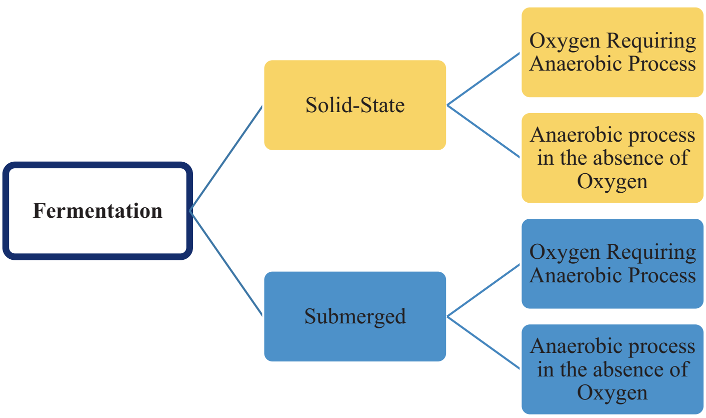


Fig. 4.22 Types of fermentation

In the fermentation of food, sugars, and other carbohydrates, they are generally converted into three products, namely, carbon dioxide, alcohol, and preservative organic acid. The use of these three products is shown in Fig. 4.23 [70].

Although fermentation is an easy and less expensive process, it offers different benefits as represented in Fig. 4.24.

Fermentation is a proven sustainable food process that has been practiced in developing countries. It is economically viable as it demands less cost and simple in nature. In addition to this, longer shelf life of the fermented food is obvious than the processed foods from other processes.

Fermented foods prevail among almost all of the developing countries. Moreover, in all of these countries, fermented foods are consumed either as main dishes or as condiments [71]. Fig. 4.25 represents an example of fermentation of a specific prod-

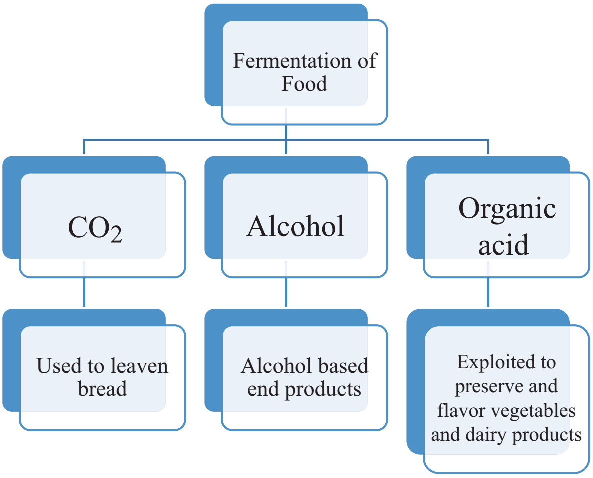


Fig. 4.23 Use of fermented products

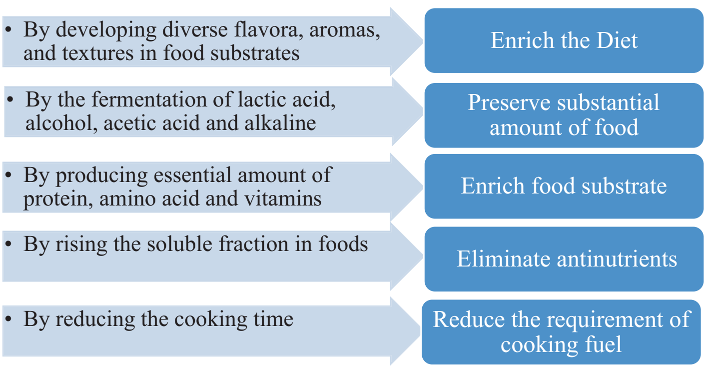


Fig. 4.24 Main purposes of fermentation

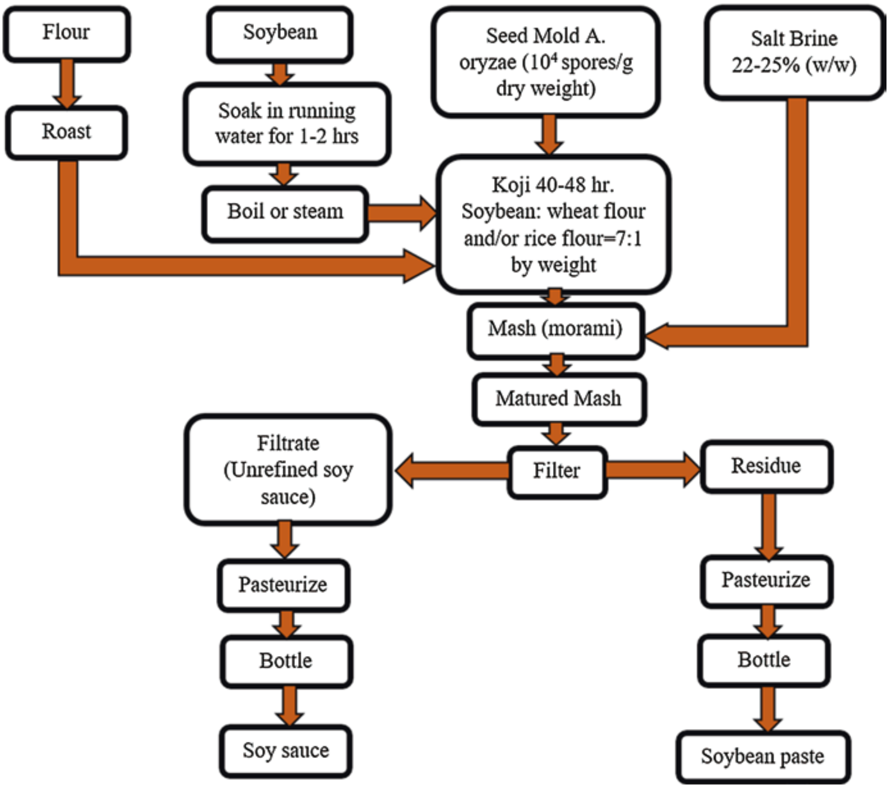


Fig. 4.25 Flowchart for the manufacture of soy sauce and soybean paste [72, 73]

uct in the developing countries. Moreover, Fig. 4.26 represents the ancient fermentation techniques of Africa [72, 73].

Fermentation is one of the most significant and energy-efficient food preservation options in developing countries. For instance, around 60% of foods consumed in famine as survival foods in Sudan is fermented foods. Moreover, there are many other countries which utilized fermentation to preserve diverse types of food as shown in Table 4.3 [68, 74].

6 Pasteurization

Pasteurization is the method of heating food, precisely liquids, to a certain temperature to slow down the microbial growth in the food. Generally, milk and fruit juices are pasteurized in developing countries. Both proper heating and cooling are associated in pasteurization as shown in Fig. 4.27 (a). Moreover, Fig. 4.27 (a) displayed the steps of pasteurization in pictorial form.

Fig. 4.26 (**a**) Ancient technique of fermentation [72, 73]. (**b**) Fermentation of fish in Africa [72, 73]

Table 4.3 List of countries which utilized fermentation to preserve different types of food [68, 74]

Area		Name of fermented foods (Some of the names are kept as local people recognized them)
Worldwide		Alcohol (beer, wine), vinegar, olives, yogurt, bread, cheese
Asia	East and Southeast Asia	Amazake, atchara, bai-ming, belacan, burong mangga, com ruou, dalok, doenjang, douchi, jeruk, lambanog, kimchi, kombucha, leppet-so, narezushi, miang, miso, nata de coco, nata de pina, natto, naw-mai-dong, oncom, pak-siam-dong, paw-tsaynob, prahok, ruou nep, sake, seokbakji, soju, soy sauce, stinky tofu, szechwan cabbage, tai-tan tsoi, chiraki, tape, tempeh, totkal kimchi, yen tsai, zha cai
	Central Asia	Kumis (mare milk), kefir, shubat (camel milk)
	South Asia	Achar, appam, dosa, dhokla, dahi (yogurt), idli, kaanji, mixed pickle, ngari, hawaichaar, jaand (rice beer), sinki, tongba, paneer
Africa		Fermented millet porridge, garri, hibiscus seed, hot pepper sauce, injera, lamounmakbouss, laxoox, mageu, mauoloh, msir, mslalla, oilseed, ogi, ogili, ogiri, iru

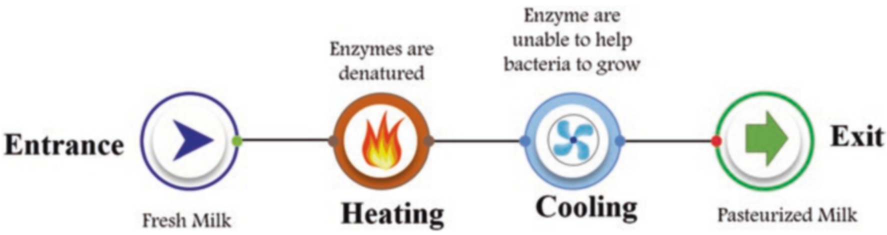


Fig. 4.27 (**a**) Steps of pasteurization. (**b**) Steps of pasteurization in pictorial form [75, 76]

Table 4.4 Different types of pasteurization [77]

Types of pasteurization	Temperature requirement (°C)	Property
Normal	118	Protein begins to denatured
Low temperature	119–150	More enzymes and proteins remain intact when milk is heated below these temperatures
High temperature	150–200	Kills enzymes, much of the healthy microorganisms, and denatures the proteins. This milk is difficult to digest
Ultra	201–280	Kills potentially harmful bacteria in the milk, but also damages all the vitamins, minerals, and other nutrients originally contained in the milk

However, if milk is heated past 150 °C, it becomes unsafe for health. The heating of pasteurization might be done by means of steam, hot water, and the products are ready after successive cooling treatment [3].

Table 4.4 shows the different types of pasteurization with their shelf life, property, and pasteurization temperature.

Although pasteurization is an effective way of liquid food preservation, it deteriorates the thermal-sensitive nutrients including fatty acids; vitamins A, B6, B12, C, and D; and minerals. In addition to this, pasteurization inactivates the naturally occurring enzymes that are vital in milk digestion.

7 Osmotic Dehydration

Osmotic dehydration has gained better consideration in current years as an efficient technique for preservation of fruits and vegetables. Banana, pineapple, mango, and leafy vegetables are the few examples that are generally preserved by osmotic dehydration in developing countries. During osmotic dehydration fresh qualities of fruits and vegetables such as color, aroma, and nutritional compounds are preserved effectively [78]. The requirement of energy is relatively low in osmotic dehydration in comparison with the other drying processes; it can also be accomplished at low or ambient temperature.

Osmosis dehydration is sometimes considered as pretreatment of other drying techniques. In that case, food drying is accomplished in two stages: removal of water using an osmotic agent such as sugar syrups and subsequent dehydration in a hot-air dryer where moisture content is further reduced [63].

Osmotic dehydration works on the principle of water transportation via a semi-permeable membrane from a low-concentration solution to a high-concentration solution. Food slices are immersed in concentrated solutions of salts or sugars. Eventually, osmotic pressure allows the transport of water toward the outside of food. Solutes such as sugar or salt enter into the food due to the difference in osmotic pressure.

However, Fig. 4.28 reveals the processes comprising of the typical osmosis dehydration of fruits and vegetables in developing countries of the world [79].

Moreover, there are several advantages of osmotic dehydration, which are written as follows [80]:

1. Less thermal sensitive quality degradation
2. High color and flavor retention resulting in the product having greater organoleptic features.
3. It raises resistance to quality during further heat treatment.
4. The process is relatively simple and economical.
5. It inhibits the enzymatic browning.
6. It develops good the texture and rehydration characteristics.
7. The blanching method can be excluded by adopting this process.

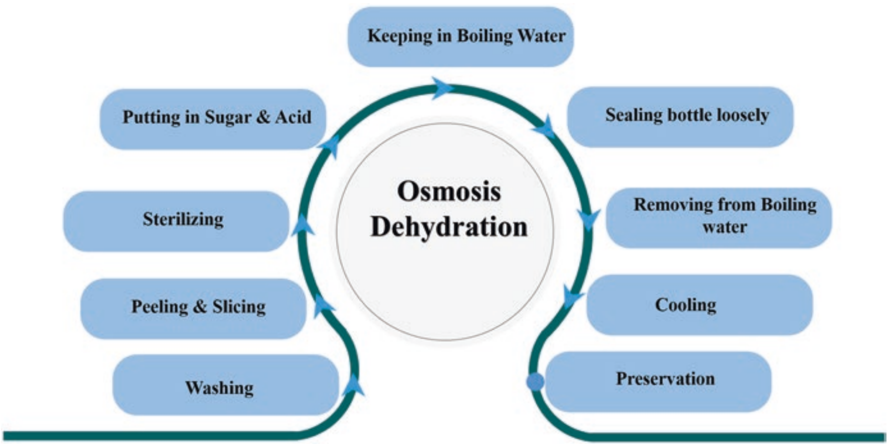


Fig. 4.28 Basic steps of osmosis dehydration of fruits and vegetables. (Adapted from Hossain et al. [79])

Table 4.5 Osmosis in developing countries

Foods	Countries	Solution	Reference
Jackfruit	Bangladesh	Sugar	[81]
Pumpkin	India	Sugar, salt	[82]
Litchi	India	Sugar	[83]
Okra	Cameroon	Salt	[84]

8. Increases the taste and acceptability.
9. The process might demonstrate to be decent for production of the ready-to-eat foods
10. The process the cost of processing, storage, and transport by reducing food volume.
11. Output products from this process retain better color.
12. This process defends against the structural collapse of the product.

Table 4.5 represents the osmosis dehydration of different food materials in the dissimilar parts of the developing world.

8 Salting

Salting is one of the oldest preservation techniques which is still being practiced across the globe. As the name of the process reflects, it is accomplished using edible salt. Salted fish and salt-cured meat are very common processed foods that are available in almost all of the developing countries due to its simplicity and low cost of processing. However, vegetables such as runner beans and cabbages are also often preserved in this manner. Owing to the hypertonic nature of salt, most bacteria, fungi, and other potentially pathogenic organisms cannot survive in food materials since they die through the salting process. Through the osmosis process generated by salting, all the living cells become dehydrated and die or become temporarily inactive [85].

For salting, it is significant that the fish or meat has been arranged in such a manner that the salt assimilated may swiftly enter into the flesh, and the moisture could leave the fish or meat.

The methods of salting meat and fish are very much identical. The common types of salting described are shown in Fig. 4.29.

In dry salting, meat or fish is packed in dry salt; otherwise, foods may be rubbed with a coating of salt. Dry salting method cannot ensure a longer shelf life as wet salting offers.

On the other hand, food is firstly rubbed with salt prior to pouring brine over the packed salted meat in wet salting or pickling. In this process, the food is kept submerged in a brine solution. Wet salting or pickling does not leave the meat as salty as in dry salting, but it is still necessary to presoak the preserved food, which take away surplus salt, before cooking [26, 86].

Wet pickling can also be classified as chemical pickling (brining) and fermentation pickling.

Sometimes, the process in which food is preserved by using an edible antimicrobial liquid is known as pickling. Brine, vinegar, alcohol, and vegetable oil including olive or mustard oil may be used as pickling agents. Heating or boiling is also involved in chemical pickling in order to increase shelf life of the preserved food with the help of pickling agent. Cucumbers, peppers, corned beef, herring, and eggs are the common chemically pickled foods.

However, in fermented pickling, the food itself creates the preservation agent, usually by a method that yields lactic acid.

Figure 4.30 shows the practical pickling processes in food preparation and preservation.

Figure 4.31 shows the pickling process of meat [26]. There are several steps by which the total pickling process is completed.

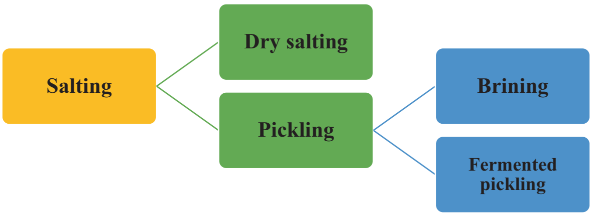


Fig. 4.29 Types of salting

Fig. 4.30 Practical processed food by pickling and salting

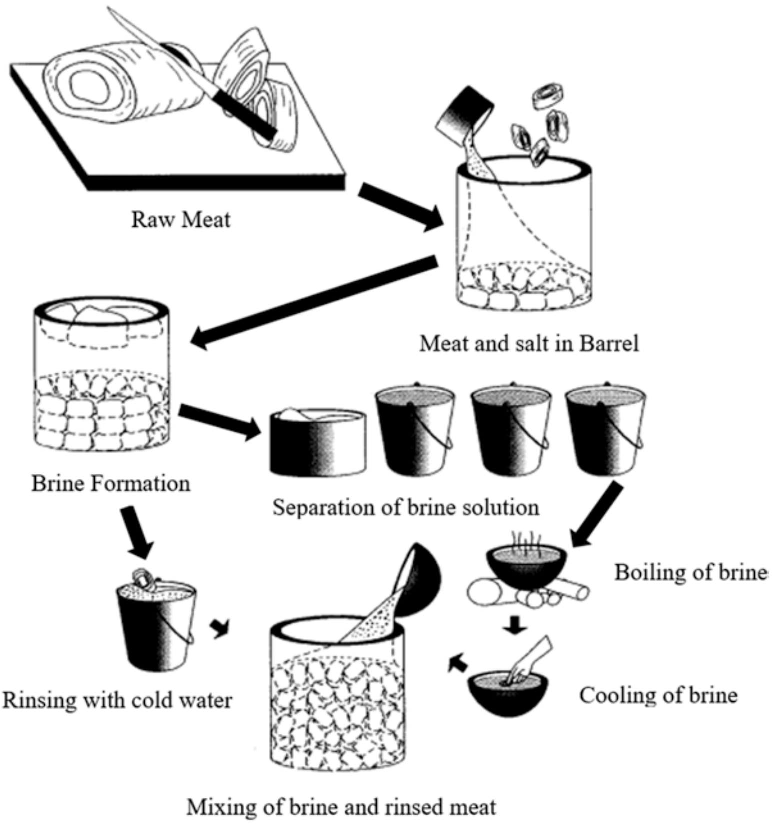


Fig. 4.31 Pickling process of meat. Adapted from [26]

8.1 Method of Working

Figure 4.32 shows the general methods and the principles of the pickling of meat. However, Fig. 4.33 shows the pickling of fish, where the process or method of working is almost similar to meat [26, 87].

9 Smoking

Smoking is one of the oldest practiced food preservation techniques for fish and meat [88]. Smoking is the method of flavoring along with cooking of food by revealing it to smoke from burning of wood. Smoking is a widespread traditional technique for food preservation in most of the developing countries. People from all cultures across the globe have relied on the smoke curing of fish and meat for long-term storage [89].

Fig. 4.32 Method of working of pickling process

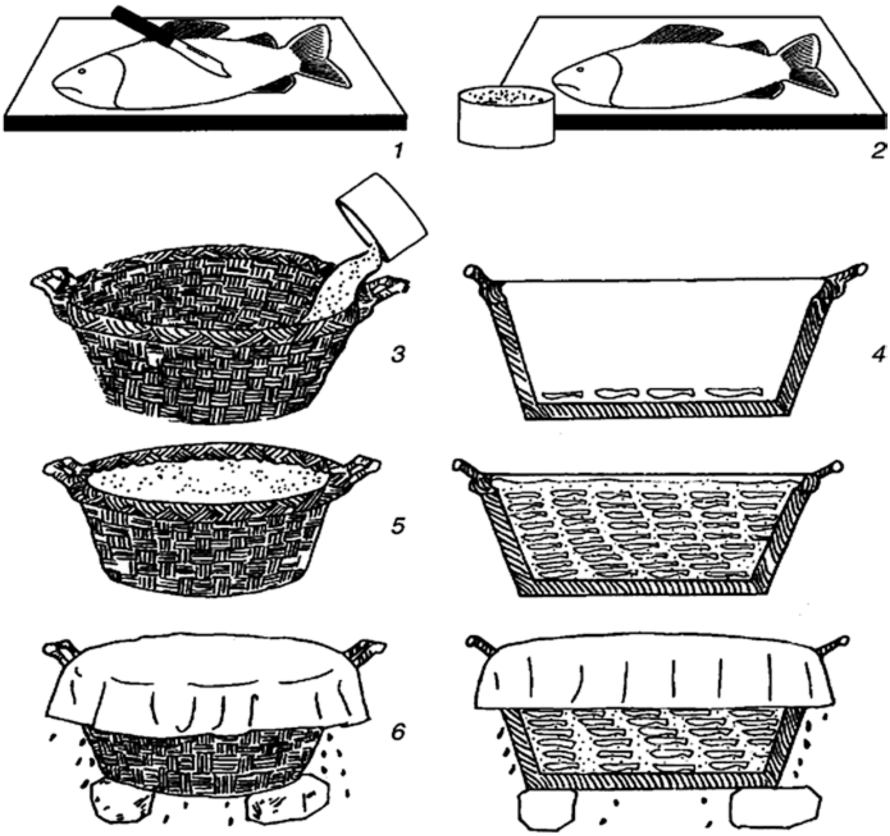


Fig. 4.33 Pickling process of fish [26, 87]. 1. Splitting, 2. Rubbing with salt, 3. Preparing thick layer of salt, 4. Placing fish, 5. Filling the bucket by repeating same phenomena, 6. Cover the bucket with plastic

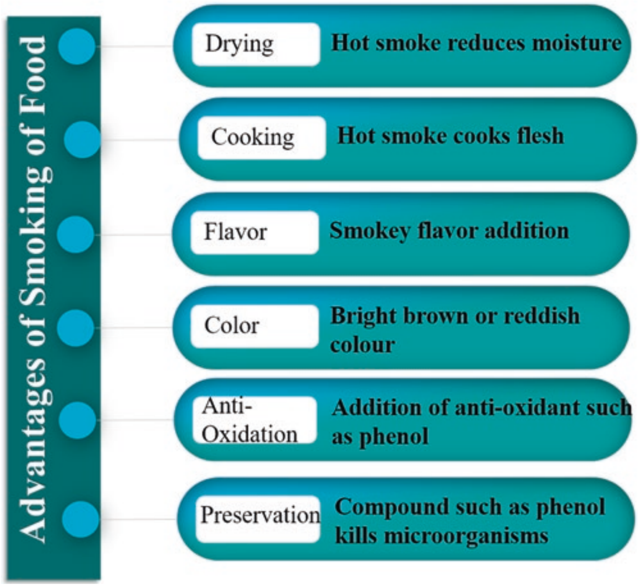


Fig. 4.34 Effect of smoking on the final product

Smoking is associated with heat transfer and dissipation of volatile composition on the surface. Smoke encompasses phenols, which has potential effect on killing of bacteria. Moreover, the high temperature of smoke also helps in cooking of food samples. Smoked food products have extensive shelf life, which has been attributed to the combined bacteria destruction, drying, and cooling effects. Moreover, smoking ensures persistent shelf life and reasonably appealing appearance of the food [90]. Overall, smoking encompasses six important effects in the product, which is described in Fig. 4.34 [91].

On the basis of the smoke temperature and duration, smoking can be classified as shown in Fig. 4.35 [26].

Cold Smoking Cold-smoked product and the fresh fish or meat have almost the same storage life. Additionally, it is problematic to regulate the process in high ambient temperatures because the temperature may not increase above 30 °C (86 °F). The cold-smoked process cannot extend the shelf life of food products. This is only done to get the smoky flavor of the foods. Due to these shortcomings, cold smoking is not used extensively as a process of food preservation. Sawdust is usually used to accomplish this type of smoking.

Hot Smoking During hot smoking, the storage life is prolonged at most 2 days. In this process, the fish or meat is heated without being dried. Clean dry wood is

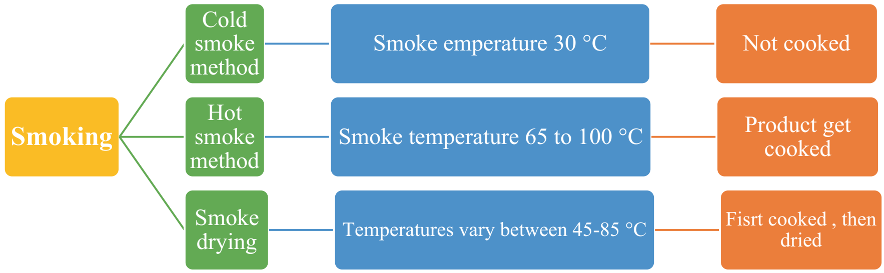


Fig. 4.35 Types of smoking and their related criteria

commonly used to accomplish this type of smoking. In this type of smoking, flame and smoke are equally required. In this type of smoking, chemical plays minor roles.

Smoke Drying Maximum traditional smoked products are in this third category. In smoke drying, hot smoke is used subsequently; the foodstuffs are dried under continued smoking. It takes almost 12–18 hours or even days, depending on the product nature and smoke quality. Occasionally, the product is salted and/or pre-dried before being smoke-dried.

The amount of smoke particles absorbed by the foods to be smoked greatly depends on the surface area of food such as fish or meat. It is also preferable to dry the raw product for an hour in the sun before smoking, which helps to avoid case hardening of the fish or meat. By doing this, the outer layer of the fish or meat would no longer permit moisture to pass through, and therefore the inside of the food would not be able to dry properly.

For obtaining the best result from smoking, it is better to do it in a dry environment. Therefore, it is better to work in a smokehouse rather than in the open air. There are different types of traditional smoking ovens available in the developing countries as shown in Fig. 4.36.

Traditional mud ovens and kilns are used in producing smoke in developing countries. The reason behind the popularity of mud ovens in developing countries is the low cost of construction along with the availability of materials. The capacity of traditional oven is small and there is much loss of smoke.

Apart from the traditional mud oven, oil-drum smoking ovens are also popular in some developing countries. In these types of oven, the control of temperature is challenging and eventually results in nonuniformly smoked food products. Also, these types of oven are very much sensitive to wind and rain.

In some cases, smoking is incorporated with salting and drying. In this combination, higher shelf life of fish has been reported in literature [94].

Fig. 4.36 Traditional pictorial view of smoking [41, 92–94]. (**a**) Practical view of smoking meat and fish. (**b**) Smoked freshwater fish at local market

10 Steeping

From the ancient time, steeping preservation has been practiced, which is done by using brine solution. In steeping, sodium chloride performs as a preserving, flavor-improving, conditioning, and taste-enhancing agent. After leaching out the salt and acid, the preserved vegetables by steeping may be used for pickling or home cooking. The animal-based foods like meat, fish, and poultry; vegetables such as tomatoes, carrot, cauliflower, cabbage, bitter gourd, peas, and mushroom; and fruits like green mango, olive, and golden apple can be preserved in an acidified sulphited brine solution [79, 95].

The steps followed by the process of steeping in order to preserve green mango are shown in Fig. 4.37 [79].

The shelf life of mango slices in brine solution is almost 8 months. PRAN group also steeps the mango slices by using the same procedure. In brief, steeping process is a combination of blanching, submerging in species, and preserving in airtight container.

The preservation techniques for olive and golden apple are almost similar as green mango, except that the blanching must be done for 3 minutes here, whereas it was only 2 minutes for mangoes. Moreover, the shelf life is also the same, that is, 8 months [79].

11 Packing

During storage and transportation, usually, two comprehensive types of damage are sustained by the fresh and the processed foods. One is physical damage for instant shock, vibration, and compressive forces. The other one is the environmental

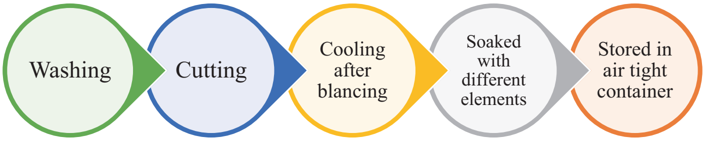


Fig. 4.37 Steeping of mango

Fig. 4.38 Packaging of food materials [96]

damage that occurs due to exposure to water, light, gases, odors, and microorganisms. Packaging system may successfully reduce these types of damages. For instance, an optimum barrier packaging can easily reduce the evaporation or oxidation of the flavor or aroma of coffee or juice. Moreover, if proper packaging is provided for protection, a shelf-stable food in a can or a pouch may maintain its stability. In addition, packaging may correspondingly enhance certain level of protection to slow down temperature changes [96].

Packing some time is deployed for short-term preservation of fresh cut fruits at room temperature and controlled low temperature depending on the expected shelf life. The way by which fresh cut fruits can be preserved for 3–4 days at 14–16 °C is presented in Fig. 4.38.

11.1 Types of Packing Materials

From the earliest times, for domestic storage and local sales of foods, many types of packaging materials have been used. A summary of the key types of packaging materials is represented in Fig. 4.39 [97].

Physical properties, gas permeability, water vapor transmission rate, type of package, and sealing reliability are the key characteristics that are needed to be taken into consideration while selecting packaging films for equilibrium modified

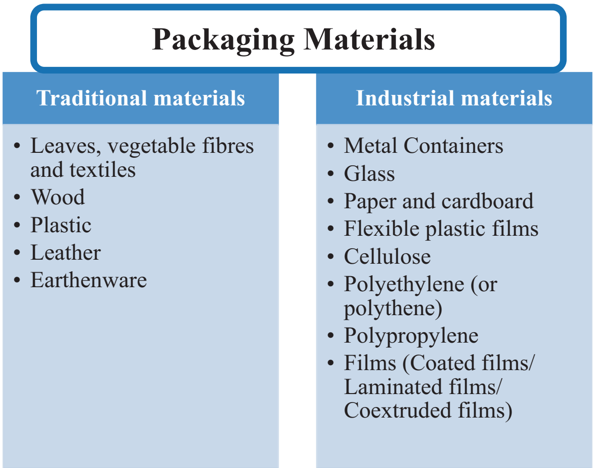


Fig. 4.39 Types of packaging materials

atmosphere packaging of fruits. Even though an increasing choice of packaging materials exists in the MAP industry, maximum of those packages are still made from four basic polymers: polyvinyl chloride (PVC), polyethylene terephthalate (PET), polypropylene (PP), and polyethylene (PE), for packaging of fruits [98–107]. Among these packaging materials, polyethylene has been extensively used for modified atmosphere packaging of fruits and vegetables [100, 108–114].

11.2 Vacuum Packaging

Vacuum packaging exemplifies a static form of hypobaric storage method that is extensively used in food industry owing to its efficacy in decreasing oxidative reactions and prevention of microorganism entrance in the product at comparatively small costs [115]. In vacuum packaging, the product is sealed in a package having low air permeability. This low permeability allows very slow diffusion of atmospheric O_2. The tiny amount of diffused oxygen is eventually absorbed in chemical reactions that usually occur within the food product [96].

However, in the meantime contents of carbon dioxide and acidity are increased, which substantially reduces the growth of aerobic spoilage microorganisms. The residual levels of CO_2 ranging from 10% to 20% in the packages are attained because of the metabolism of the product tissue and existing microorganisms [49, 116].

Moreover, the accurate balance of O_2 and CO_2 in the vacuum packaging saves foods from desiccation and rancidity during storage [117].

Due to the three oxygen barrier properties of the packaging material, inhibition in the development of aerobic spoilage organisms and slowing down of deleterious oxidative reactions in the food during storage are achieved. There are several factors, as mentioned in Fig. 4.40, that are needed to be maintained for the films used for vacuum packaging in large-scale production methods, particularly, in the case of films used in pasteurization.

Most of the fruits and vegetables can be preserved using vacuum packaging as shown in Fig. 4.41 [118]. However, the extension of shelf life significantly depends on the types of food materials and its moisture distribution. For longer life, food materials should be dried enough to prevent proliferation of microorganisms.

Requirements of film used in vacuum Packaging					
High durability	Retention of flexibility even at low temperatures	Impermeability to liquids, comprising oils and fats and macromolecules	Manufactured from non-toxic, food acceptable, odorless materials	Near Impermeability to gases	Capability to resist heating to at least 150°C

Fig. 4.40 Requirements for film used in vacuum packaging

Fig. 4.41 Practical application of vacuum packaging [118]

12 Evaporative Cooling

Cooling processes such as refrigeration are not also affordable to small farmers, retailers, and wholesalers [119, 120]. Moreover, several tropical fruits and vegetables like banana, tomatoes, orange, leafy vegetables, etc. cannot be stored in the refrigerator because they sustain chilling injury and color change [121, 122]. The use of chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants in refrigeration system is partly responsible for ozone layer depletion and global warming [123]. Because of these reasons, its application has become limited. Evaporative cooling storage structure is an alternative of mechanical refrigeration system [124].

Evaporative cooling storage system has numerous advantages over refrigeration system, as it does not use refrigerant so it is eco-friendly (reduces CO_2). It has also some other advantages as discussed below:

- It does not make noise as there is no moving part.
- It does not use electricity, i.e., it saves energy.
- It does not require high initial investment, and operational cost is negligible.
- It can be quickly and easily installed as this is simple in design. Moreover, its maintenance is easy.
- It can be constructed with locally available materials in remote area, and most importantly, it is eco-friendly as it does not need chlorofluorocarbons [124–127].
- Evaporative cooling decreases temperature and increases humidity, which is a suitable combination of parameters for storage of agriculture produce [127, 128].

Evaporation is a simultaneous heat and mass transfer process. During evaporation, moisture migrates from the surface of the food sample to its surrounding. The water molecules with higher kinetic energy evaporate from the surface. Consequently, the average energy of the remaining water molecules decreases significantly that leads to a lower temperature at the exposed surface of the sample. Due to this special consequence of decreasing temperature, this phenomenon is coined as evaporative cooling.

12.1 Methods of Evaporative Cooling

The two common approaches consist of direct and indirect evaporative cooling.

12.1.1 Direct Cooling

Cooling air passes through a moist material where evaporation takes place and cooling effect occurs in direct evaporative cooler (DEC). Then the cooled moist air is directly permitted to transfer into the conditioned space. In contrary to this, in indirect cooling practices, a certain form of heat exchanges that use the cool moist air is produced through the evaporative cooling to lower the temperature of the drier air. Then the exhaust from the indirect evaporative cooler, that is, the cool dry air, is used to cool the environment, and after that the cool moist air is expelled [129].

To cool the water, direct evaporative cooling is usually used. This method typically uses a porous clay vessel or a watertight canvas bag in which water is kept. These vessels are then either hung or placed so that the wind can flow over them. This process of evaporation slowly cools the water. The mechanism of direct evaporative cooling is displayed in Fig. 4.42.

12.1.2 Indirect Evaporative Cooling

The level of humidity in the air obtained from the direct cooling is very high, which is unwanted for several applications. Indirect evaporative cooling can be utilized to resolve this problem. In this method, the evaporative-cooled moist air cool the drier air through heat exchanger. The resulting cool air is then used to cool the conditioned space [130]. Each of the systems of indirect evaporative cooling necessitates power to run both water pump and fans. Therefore, indirect evaporative cooling has inadequate applications. The mechanism of indirect evaporative cooling is displayed in Fig. 4.43.

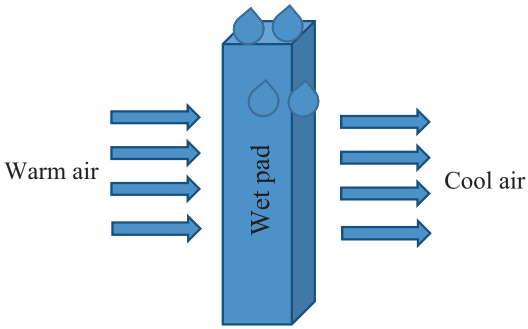


Fig. 4.42 Direct evaporative cooling (DEC)

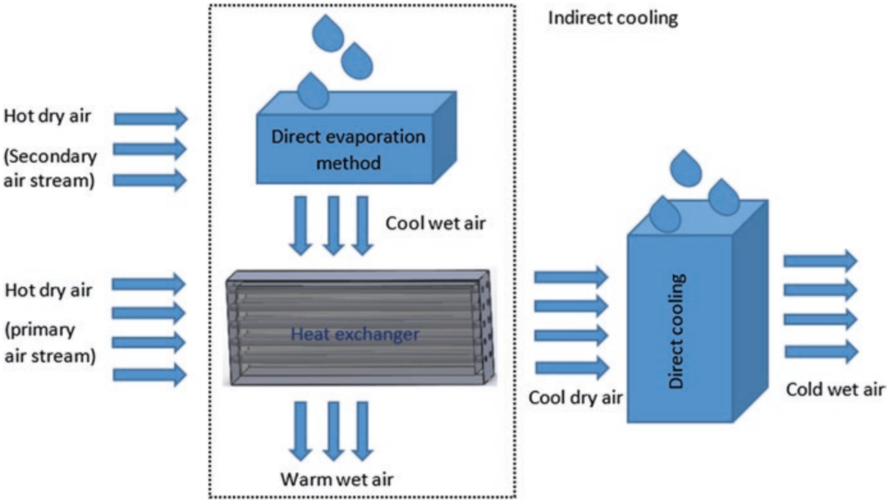


Fig. 4.43 Indirect evaporative cooling (IDEC)

12.2 Application of Evaporative Cooler in Food Storage

Evaporative cooling has been used to store food products by numerous companies. Both of the two methods of evaporative cooling are used to design the storage system in different cases.

12.2.1 DEC for Preservation of Food

DEC is a very ancient method of cooling. This method is simply passing the inlet air through a wet porous humidifier. Both dropping of the temperature and increasing the humidity of the inlet air can be obtained by the direct evaporative cooling system. There are numerous simple passive evaporative coolers that are accessible for local farmers to preserve agricultural product [131]. Some of these cooling techniques are pot in pot, static cooling chamber, charcoal cooler, and cabinet cooler.

Pot in Pot

As evaporative coolers consist of a wet porous bed, cooled and humidified air can be attained to preserve food in a pot in pot arrangement [120]. An example of pot in pot that is designed and developed by the Food and Nutrition Board of

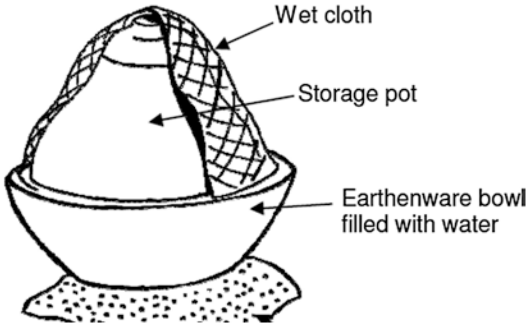


Fig. 4.44 Schematic diagram of an evaporative cooling using wet porous bed. Adapted from [133]

India has been shown in Fig. 4.44 [132]. The fundamental design comprises of a storage pot positioned inside a bigger pot. The inner pot stores food; whereas, the larger pot contain water to facilitate evaporative cooling phenomenon as demostrated in Fig. 4.45.

Static Cooling Chamber

The Indian Agricultural Research Institute constructs a cooling scheme that can be constructed using locally obtainable materials, which is called static cooling system [132]. Bricks and river sand are the basic components used to make this type of cooler. However, a cover made from cane or other plant materials and sacks or cloth can also be used in this type of cooler as represented in Fig. 4.46. Also, there must be a close source of water. After completing the construction of the walls and floor, the sand in the cavity is systematically saturated with water. When the chamber is entirely wet, two-time daily scattering of water is done that is sufficient to sustain the wetness and temperature of the chamber.

Charcoal Cooler

The charcoal cooler is made from an open timber frame as shown in Fig. 4.47. The wooden frame of the system encompasses charcoal between two meshes. The charcoal is sprayed with water; hence, the wetness provides an evaporative cooling [135]. The top of the box is usually made from any solid and thatched to keep safe the food from flying insects.

All cooling chambers should be placed in a shaded area with ensuring enogh exposure of dry air. Airflow can be artificially created using a chimney the resulting draft draws cool air into the cabinet situated below the chimney. Wire mesh shelves and holes in the bottom of the raised cabinet ensure the free movement of air passing over the stored food as shown in Fig. 4.47.

Fig. 4.45 Evaporative cooling using wet porous bed [133]

Fig. 4.46 A static cooling system [134]

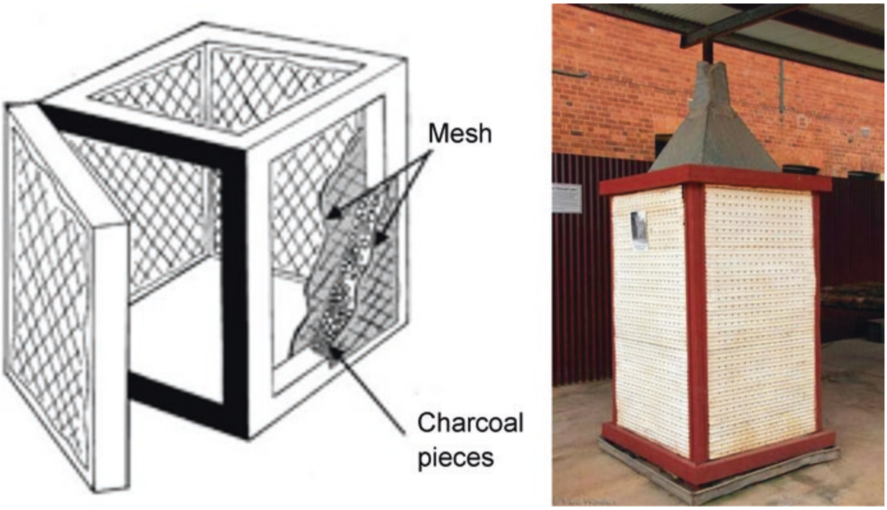


Fig. 4.47 Charcoal cooler [136]

12.2.2 IDEC for Preservation of Food

By the help of the equipment design, the draft air is processed twice or more in indirect evaporative cooling. They normally use precooler for the primary air before passing it to the next stage of cooling [137]. Fundamentally, there are two categories of indirect evaporative coolers. They are the dry and wet surface type. They are categorized depending on the mode of heat and mass transfer process in the heat exchangers [138].

Two-Stage Evaporative Cooler

A researcher developed an improved evaporative cooler named two-stage evaporative cooler (TSEC) that can increase the efficiency of evaporative cooling for high humidity and low-temperature air conditioning, which is represented in Fig. 4.48 and Fig. 4.49 [139]. In TSEC there are two evaporative cooling chambers and a heat exchanger. There are several factors such as temperature drop, efficiency of the evaporative cooling, and effectiveness of TSEC over a single evaporation, upon which the performance of cooler has been evaluated. TSEC can reduce the temperature ranging from 8 °C to 16 °C.

It was detected that TSEC can decrease the temperature up to wet-bulb depression of ambient air. The effectiveness of the two-stage evaporative cooling was found to be 1.1–1.2 over single evaporation. The two-stage evaporative cooler delivered the room conditions as 17–25 °C temperature and 50–75% relative humidity, which may increase the shelf life of the extensive variety of fruits and vegetables with reasonable respiration rates.

13 Frying

Frying is one of the extensively used and cost-effective food preservation techniques [140]. Shelf life of foods including fruits and vegetables is extended along with enriched flavors in frying process. Conversely, improper frying oil may have injurious effects on the consumers' health [141].

To maintain the quality and the shelf life of fruit and vegetables are converted into chips by frying. Low moisture content makes the Chips long-lasting than fresh fruits or vegetables [142]. Fruits which are turned into chips require technological consideration to make the processed chips suitable for consumers. Vacuum frying is one of the ways which can produce healthy food without changing its original form [143].There are generally two common types of frying that are practiced to process foods, namely, traditional deep-fat frying and vacuum frying [144].

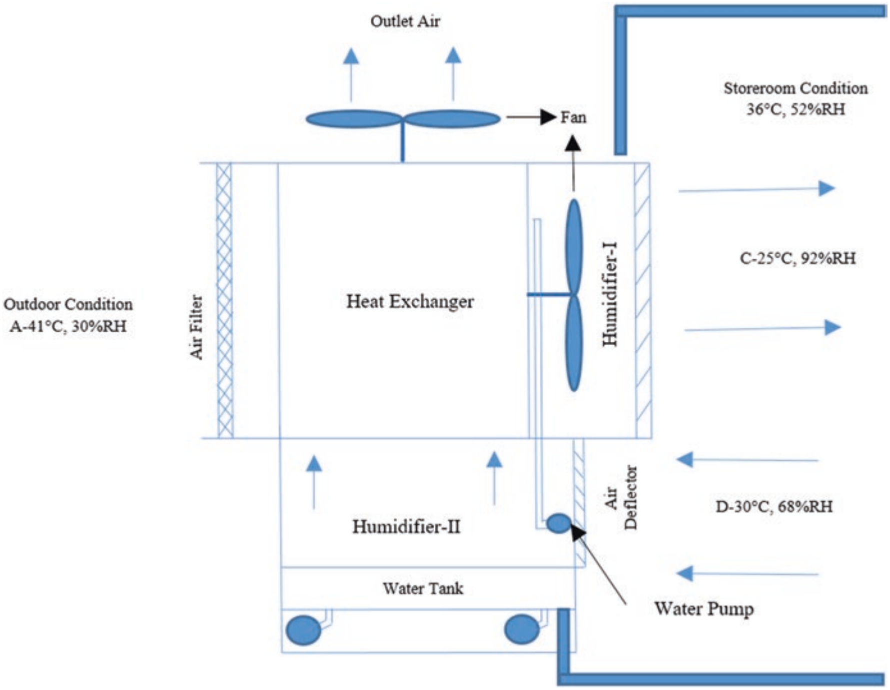


Fig. 4.48 Schematic diagram of a Two-stage evaporative cooler (TSEC). Adapted from [139]

Fig. 4.49 Two-stage evaporative cooler (TSEC) [139]

13.1 Deep-Fat Frying

Deep-fat frying is one of the ancient food preparation methods and is extensively practiced in the food industries. Frying is a technique that is fundamentally the immersion of food pieces in hot vegetable oil, at a temperature of above the boiling point of water [145]. This condition enables higher proportions of heat transfer, to facilitate water evaporation. Also, during the frying an oil layer covering the product surface is created [146, 147]. To define the moisture evaporation and oil absorption in deep-fat frying, numerous models have been formed [148–150]. There are different frying operation variables controlling mass transfer in deep-fat frying, such as oil temperature and frying time [151]. To retain all the flavors and juices by a crisp crust, deep-fat frying seals the food by immersing it into hot oil [152, 153]. Frying is usually done in atmospheric pressure at a high temperature. Throughout the deep-fat frying process, food is rapidly cooked and browned, and the texture and flavor are generated [154]. Consequently, deep-fat frying is frequently designated as a technique for producing exceptional flavors, colors, and textures in processed foods. Owing to the higher heat treatment, surface darkening and various additional adverse responses could happen before the food is completely cooked [155].

Usually, frying temperature may range from 130 °C to 190 °C, but the most common temperatures are 170–190 °C.

Fish is preserved after deep frying in many developing countries including Bangladesh, India, Myanmar, and Nigeria, which is shown in Fig. 4.50 [157–159].

13.2 Vacuum Frying

Vacuum frying is a favorable tool which can be a significant option for the production of novel snacks, for instance, fruit and vegetable chips, that deliver the desired quality attributes and respond to new health trends [160]. Although fruits and vegetables are the essential sources of vitamins and antioxidants, the average

Fig. 4.50 Preservation of food by deep frying [156]

consumption rate of these foods is decreasing in modern societies due to the early decay and rather high price [161]. Fruits and vegetables have higher sugar content and are heat sensitive; therefore, they are typically burned in the temperature of normal frying process. These foods lose their normal colors and tastes if they are fried at low temperature [162].

To solve this problem, vacuum frying can be a substantial option as it can be performed at low temperatures and minimal exposure to oxygen [163]. By doing this, the anticipated crispy texture and higher nutritional value products can be obtained [163]. Food is heated in a low pressure to attain reduced boiling points of frying oil [152]. When the oil temperature reaches the boiling point of water, then the water may be removed from the fried food quickly. As the food is heated at a lower temperature and oxygen content, colors and tastes may be preserved in superior condition in vacuum-fried food [164, 165]. The nonexistence of air throughout the frying process may constrain the oxidation comprised of lipid oxidation and enzymatic browning; hence, the color and nutrients of food may be extensively preserved [166, 167].

Dehydrated food produced by vacuum frying may have crunchy texture, decent color, taste, and better retention of nutrients. Moreover, vacuum frying reduces the negative effects caused by the oil [168]. Fig. 4.51 shows the schematic of the vacuum frying system.

In many developing countries, frying is followed after sun drying. For instance, sun-dried camel meats are cut into small pieces before frying for long-time preservation in Somalia.

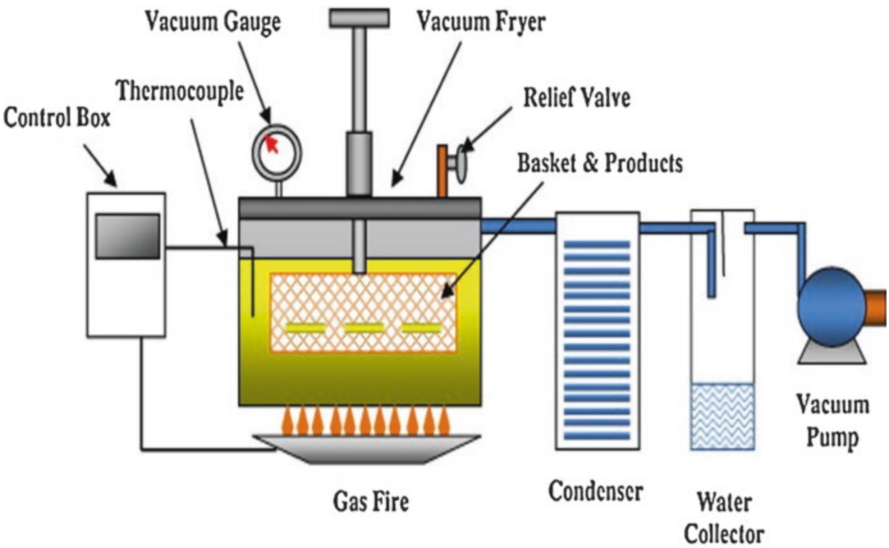


Fig. 4.51 Schematic of the vacuum frying system [169]

14 Storage

Many varities of food storage techniques are practiced in individual and commercial scale in the developing countries of the world [87–89]. However, most of modern storage facilities are highly energy-intensive and not sustainable for the food storage in developing countries. On the other hand, there are some traditional systems used in the developing countries of the world, where food can be left without special storage arrangements up to less than a day to several months depending on their perishability as shown in Table 4.6 [170].

Probably as old as drying, it is one of the ways the villagers in Ha-Makuya used to preserve farm products. Usually, onions, tomatoes, mangoes, oranges, and sweet potatoes are kept under the shade after harvesting, particularly by hanging them under the tree to ensure maximum shade cover [171].

14.1 Underground Storage

There are some indigenous techniques of food storage comprised of storing in baskets, and storing cocoyam and potatoes in the soil to inhibit spoilage. Diverse traditional approaches of storage, for instance, heap storage, in-ground storage, and platform and pit storage systems, have been practiced in Nigeria and other African countries. However, the most common traditional technique is the pit storage. Pit storage of food including sweet potatoes has been reported in Indonesia, Zimbabwe, and Malawi by Woolfe [172] and in Nigeria by Awojobi [173]. Pit storage is commonly considered economical for the rural communities since it necessitates least amount of materials.

Sandifolo et al. [174] stated that the chemical composition of sweet potatoes is not much affected after 4 months of storage. According to Yakubu [175], the pit storage technique seemed to be the best traditional process because deteriorations such as sprouting moisture loss and pathological losses are minimal compared with other storage approaches. This approves the earlier results of Mbeza and Kwapata (1995) who correspondingly specified that in Malawi the pit storage technique is the most common traditional technique of sweet potato storage [176]. This pit is called

Table 4.6 Storage life of some fresh foods at normal atmospheric conditions [171]

Food	Terminology	Storage life
Meat, fish, and milk	Perishable	1–2 days
Fruits and vegetables	Semi-perishable	1–2 weeks
Root crops	Semi-perishable	3–4 weeks
Grains, pulses, seeds, and nuts	Nonperishable	12 months

Fig. 4.52 Traditional storage structures commonly used by the farmers in Bangladesh [170]

nkhuti, and they facilitate the preservation of their sweetness and might be used for storage for 1 year [177]. Fig. 4.52 presents the traditional storage structures that are generally used by farmers in the developing countries of the world like Bangladesh.

However, in the following section, a snapshot of the available food storage techniques of Bangladesh has been presented. The people of remote areas are the main practitioner of traditional food storage systems. Container, mud silos, and bamboo silos are also introduced in different parts of Bangladesh hoping to receive better storing results.

Moreover, implementation of silo also helps to protect the preserved foods from insects. Among the different types of silos, mud silos are mainly used in the rural areas of Bangladesh as represented in Fig. 4.53. Mud silos are more suitable for the dry tropics as these allow moisture migration from outside through the wall, which may increase the possibility of fungal growth. The moisture injection into the silos

Fig. 4.53 Silos (a) mud (b) bamboo

can be prohibited by mixing cement with the clay. Additionally, painting or coating of the outer wall can offer the same better outcome.

Mud silos should be protected from the heavy rainwater; otherwise, it will be damaged. Mud silos are easy to construct compared with the other silos. To store the commodities in dry and wet season properly, brick and cement silos are used. They also need the roof support and the protection from the floor [178]. The bamboo silos are suitable for maize cobs are made of bamboo for leg and side support and for roof support, palm leaf, as well as thatching grass, are used. This construction is suitable during the time when the moisture level is decreasing daily by 70% especially during the low rainfall season. In this case, the drying process is occurring continuously due to the natural ventilation. But it is not so safe from the attacks of the insects [178].

Taken all the limitations into consideration, warehouses and godowns are now available in the different cities of Bangladesh [179]. Cold storage, as shown in Fig. 4.54, is the most implemented and preferable method for storing perishable commodities including dairy products in Bangladesh [180, 181].

In recent years, so many government and private warehouses, silos, and depots have been installed in Bangladesh. Every warehouse is designed for particular types of commodities depending on their storage time and the type of product, although their ultimate goal of preserving the commodities remains the same.

More or less the country is provided with warehouses for the seasonal and emergency storing purpose. There is a total of 5 silos, 13 central storage depots (CSD), and 600 local supply depots (LSD) situated at strategic locations all across the country [182].

Fig. 4.54 Cold warehouses. Adapted from [181]

15 Jam and Jelly

Jam and jellies are products prepared mainly from fruits; however, they may correspondingly be prepared from some vegetables such as sweet potatoes, tomatoes, carrots, and some legumes. Jam and jelly making are also known as homemade heat treatment-based food preservation method. Jam is cooked fruit that is usually boiled with 65% sugar. The basic principle of preserving food by sugar is described in the subsequent section

- Sugar dissolved in food forms a solution with a low water concentration.
- Microbial cells have a high water concentration, and the cells are enclosed by a semipermeable membrane.
- The water is drawn out of the microbial cells by osmosis, and the cells are dehydrated and destroyed.

Figure 4.55 represents the principles of preservation of food by sugar. In jam making four basic principles are usually followed:

- High temperatures are used to destroy enzymes and microbes in the fruit.
- Jam is sealed in pots to prevent reentry of microbes.
- 65% sugar prevents microbes from growing in jam once opened.
- Pectin, acid, and sugar make jam set.

A simple formula is used to calculate the formulation to attain a jam or a jelly. The mass of product attained for a particular mixture of fruit or fruit juice and sugar is calculated by the following equation. Typically, an identical amount of fruit and sugar is mixed at the start of the method: if less sugar is used, more water must be evaporated, and a reduced yield will be attained.

However, jam and jelly are not a suitable product for patients who have glycemic problems, obesity, diabetes, and cardiovascular diseases as these are very high energy-intensive products. Therefore, producing jam and jelly with low sugar contents can be a substantial solution to this issue. However, special types of pectin are required without which there would have been a significant problem in product texture, stability, and uniformity.

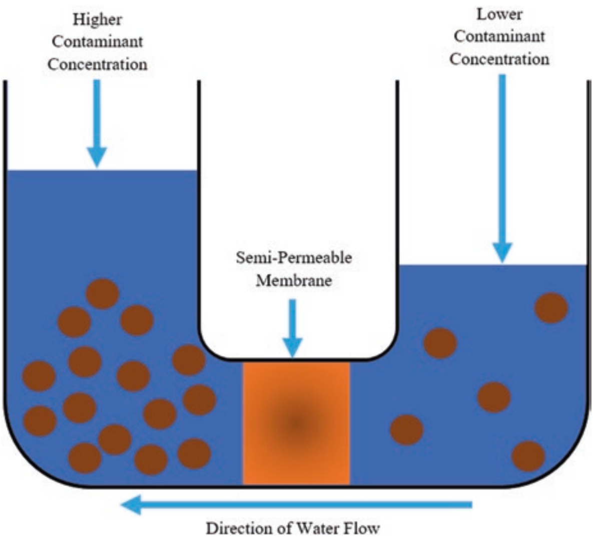


Fig. 4.55 Principle of preservation of food by sugar. Adapted from [183]

There are various food preservation techniques practiced in developing countries. These techniques are based on trial-and-error experiments that have taken place for generations. Although there are many advantages in traditional preservation systems, huge scope of improvement prevailed. The challenges in traditional food preservation techniques and their potential solutions are discussed in the proceeding chapters.

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Chapter 5
Effectiveness of Food Preservation Systems

Abstract Food without adequate nutrition cannot serve the purpose of its consumption. The main purpose of food preservation is to retain as much nutrition as fresh foods contain. Maintaining a fresh quality of preserved food does not get proper attention in developing countries. Many advantages such as low initial and maintenance cost, ease of operation, and maintenance can be measured with local materials which are embedded in traditional food preservation techniques; however, energy efficiency and processing time of the traditional preservation techniques are not at a satisfactory level in most of the cases. Overall quality including shelf life can be improved to an appreciable extent. In order to improve energy efficiency, processing time, as well as quality attributes, mistakes and challenges associated with traditional food preservation must be addressed properly. On the other hand, improper preservation may hinder the food safety in the long run. In this chapter, the overall performance of food preservation techniques practiced in developing countries has been extensively discussed.

A food preservation system can be mentioned effective only when it is able to assure food stability from all kinds of food spoilage that can occur from different sources such as chemical, microbial, and enzymatic reaction. The reaction between food constituents and ambient oxygen, microbial growth, and enzymatic and unexpected chemical reaction among food constituents are the key reasons for food spoilage. An effective food preservation system should be capable of minimizing all the causes efficiently. Therefore, taking this issue into consideration, it is better to prevent the microbial spoilage especially and to minimize the activation of the enzyme and chemical reaction to an acceptable extent.

There are many ways to determine the effectiveness of a food preservation and are available in literature. However, in this chapter, the overall efficiency perception is kept limited with the aspect of cost, quality, shelf life, as well as energy requirement as shown in Fig. 5.1.

There are different food preservation systems that have a range of effectiveness in terms of shelf life enhancement, quality enhancement, and energy and cost

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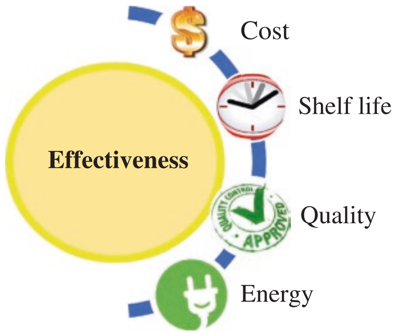

Fig. 5.1 Effectiveness of food preservation system

reduction. An extensive discussion about the effectiveness of different food preservation techniques has been presented in this chapter.

1 Shelf Life Enhancement

Shelf life varies between foods at their fresh state. Proliferation of microorganisms, oxidation, enzymatic reaction, and other damages cause reduction of shelf life of food materials. Food preservation plays a vital role in extending shelf life. Different preservation techniques offer varied degree of shelf life extension. Moreover, the effectiveness of the preservation affects the length of shelf life significantly. In the following sections, shelf life extension by different food preservation techniques has been discussed briefly.

1.1 Fermentation

In food processing, fermentation can be considered as a process, whereby it uses microorganisms like yeasts or bacteria—under anaerobic conditions, carbohydrates are converted into alcohols or organic acids [1]. The key functions of fermentation are represented in Fig. 5.2.

A number of researchers have done extensive investigation to evaluate the effect of fermentation on the shelf life of different foods. Basically, in the fermentation process, food may be well-maintained up to 6–18 months. For example, adequate nutritious foods may be obtained from the fermentation process of vegetables that can be kept for prolonged periods, usually 1 year or more, without the help of the refrigeration process. However, an inappropriate fermentation originates substantial development of unexpected microorganisms.

A research was conducted on kimchi, and it was found that the application of bacteriocin *Leuc. citreum* GJ7 as a starter culture improves the resistivity of microbial growth, avoids excess ripening, and prolongs the shelf life about 125 days [2]. Another research was conducted on wheat bread, and it was found that fermentation

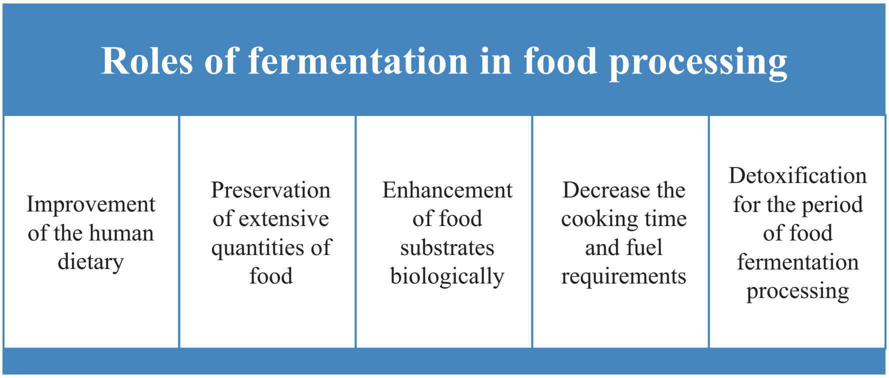

Fig. 5.2 Basic functions of fermentation in food processing

with the antifungal strain *Lactobacillus plantarum* FST 1.7 intensified the shelf life to a significant magnitude [3].

Moreover, Kacem and Karam monitored the counts (logCFU/g) of microbial groups in Algerian green olives during fermentation. They found that the microbial group does not cross to a damageable region for up to 90 days. The outcome has been extensively represented in Table 5.1.

Shelf life extension of fermented food mainly depends on the proliferation of favorable microorganisms. The effectiveness of fermentation depends on the quality of water, presence of air, and temperature of the system. In many a cases, people of developing countries keep less attention in appropriate fermentation temperature and other related issues. Consequently, relatively shorter shelf life has been observed in the fermentation foods in rural areas.

1.2 Canning

Canning prevents microorganism growth and inactive enzymes. Canning can be done both in commercial stage and home, but commercial canning food may last for many decades if the canned food is stored at a temperature around 75 °F or below, whereas the shelf life of homemade canning food shows lower than commercial one. Moreover, it is obvious to ensure that canned food should not be stored in freeze as there is a great risk of food volume expansion that may subsequently cause the breaking of jar/can.

In general, fruits and vegetables in cans and bottles produced under commercial sterility can be used up to 2 years and longer. If proper heating is not accomplished during canning, *Clostridium botulinum* bacteria may start developing, and it finally may cause a severe form of food poisoning. Therefore canning should be done properly so that it may sustain all the quality attributes along with ensuring a higher level of shelf life. The enhancement of shelf life due to proper canning in the commercial stage for some selected food is presented in Fig. 5.3 [5–8]:

Table 5.1 Monitoring the counts (logCFU/g) of microbial groups in Algerian green olives during fermentation [4]

Microbial group	Fermentation period (days)		
	15	60	90
Total aerobic count	4.52	7.76	6.88
Coliforms	2.12	2.33	1.96
Staphylococci	2.03	2.52	1.35
Lactic acid bacteria	3.8	6.55	6.96
Lactobacilli	3.6	5.55	5.66
Yeasts	1.88	3.84	5.98
Psychrotrophs	4.22	3.88	1.53

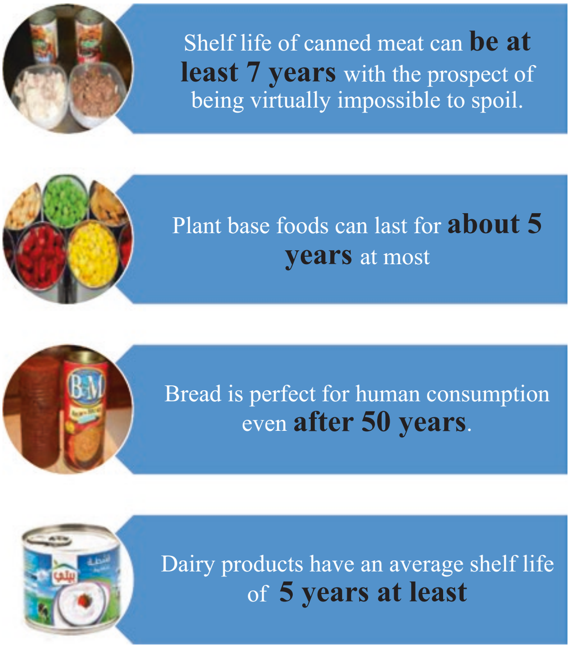

Fig. 5.3 Shelf life of different food materials [5–8]

In developing countries, people quite regularly make great mistakes in heating and pressurizing during canning. Moreover, proper sealing is not quite easy for the rural people. Due to these challenges and mistakes, shelf life of traditionally processed canned food is not as prolonged as it is found in developed countries.

1.3 Packaging

In food science, the main purpose of packaging is to store processed food materials in order to increase the shelf life. If proper packaging is provided for protection, a shelf-stable food in a can or a pouch may maintain its stability especially against

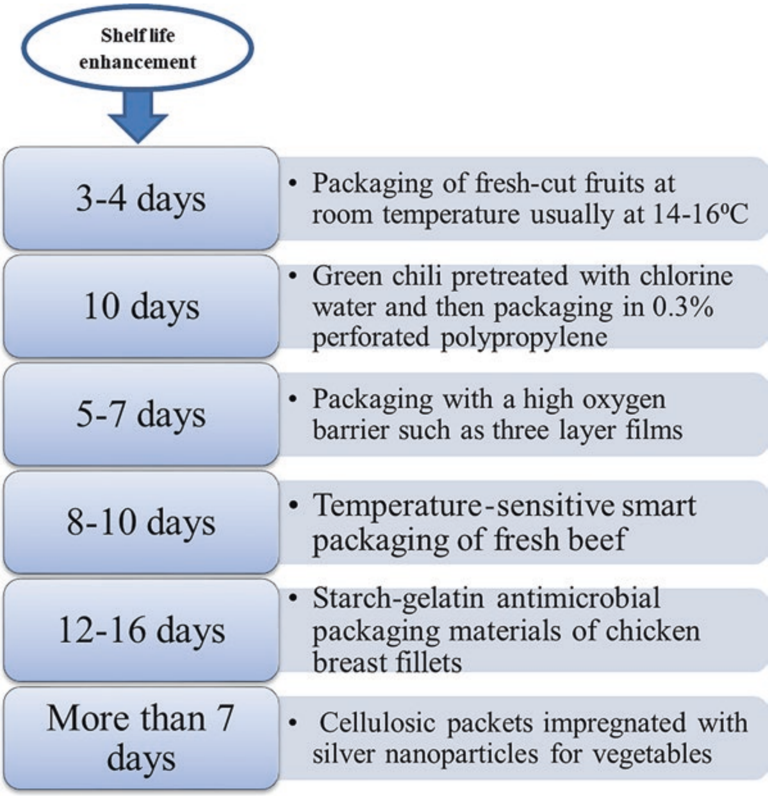

Fig. 5.4 Positive outcomes of proper packaging of different types of food materials [9–14]

microorganisms. In addition, packaging may correspondingly enhance a certain level of protection to slow down temperature changes. Even fresh or less processed foods in appropriate packaging can be kept without losing significant quality. The positive outcomes of proper packaging of different types of fresh or less processed food materials are represented in Fig. 5.4.

Apart from these, there are many more examples of shelf life enhancement by implementing proper packaging techniques [15–20]. All the established food packaging techniques will be helpful in preventions of microbial growth at varied conditions and will enhance the shelf life of different food materials in a considerable manner.

The types and quality of packaging materials remarkably affect the packaging performance. Although there is no complex physics involved in packaging, low shelf life of packaged food can be observed due to incorrect selection of packaging materials. Most of the time, low-grade packaging materials used in developing countries cannot offer high shelf life. Therefore, the selection of packaging materials should be appropriate to retain food at high quality for an extended time.

1.4 Storage

Food storage permits food to be consumed for a certain period (usually weeks to months) after harvest rather than exclusively instantaneously. There are many food storage techniques which are practiced at individual and commercial scale in the developing countries of the world [21–23]. However, most of these are highly energy-intensive processes which in turn are not sustainable for the food storage purpose. There are some traditional systems used in the developing countries of the world, where food can be left without special storage arrangements up to less than a day to several months depending on their perishability. However, if proper storage conditions are maintained, the shelf life of food can be increased in a considerable manner. The effect of food storage of some of the selected food materials at optimum temperature and humidity is extensively represented in Table 5.2 [24–26]:

Moreover, there are also some selected food materials, and if these are properly packaged and stored unopened in a cool, dark, or dry environment, then the shelf life of these food materials can be increased significantly which is represented in Table 5.3.

The performance of storage systems depends on a set of parameters including temperature, relative humidity, light intensity, and airflow. The abovementioned shelf life extension of food materials that are kept in storage system are the average values. However, superior or inferior performance may be observed in the case of variation of the conditions. Therefore, lower shelf life of the stored food in developing countries is not beyond expectation. As the maintenance of the proper storage conditions is quite difficult, the shelf life is found relatively lower in rural areas in developing countries.

1.5 Evaporation Cooling

Evaporation cooling offers a considerably lengthier shelf life of exceedingly perishable fruits and vegetables. There are several major factors upon which the rate of evaporation is dependent. All the factors are interconnected with each other and influence the rate of evaporation. The factors influencing evaporation cooling is shown in Fig. 5.5:

The highest cooling potential depends on a set of factors including simultaneous heat and mass transfer process parameters such as the temperature of the surface and air, relative humidity, and thermal properties of water. For instance, if the dry and wet bulb temperatures were 32 °C and 12 °C, respectively, the subsequent reduction in surface temperature may theoretically be 20 °C. But in reality, it is not possible to attain 100% of the theoretical temperature drop. However, an appreciable extent of reduction in surface temperature can be expected.

If all the factors are maintained appropriately, then the shelf life of foods can be extended significantly by the evaporative cooling method. The ideal storage

Table 5.2 Storage life of selected foods at optimum temperature and humidity [24–26]

Product	Optimum temperature (°C)	Relative humidity (%)	Storage life
Fresh products			
Apple	−1 to 4.5	90–95	1–12 months
Asparagus	2	95–100	2–3 weeks
Avocado	3–13	85–90	2–8 weeks
Banana	13–15	90–95	1–4 weeks
Blueberries	0.5–1	90–95	2–3 weeks
Broccoli	0	95–100	2 weeks
Cabbage	0	95	2–3 months
Cucumber	7–10	95	2 weeks
Eggplant	8–12	90–95	1 weeks
Ginger	13	65	2.5 weeks
Guava	5–10	90	2–3 weeks
Green beans and field peas	3–7	95	5–10 days
Leafy vegetables	0	95	1–2 weeks
Lime	9–10	85–90	6–8 weeks
Mango	13	90–95	2–3 weeks
Onion	0	70	2–3 months
Papaya	7–13	85–90	1–3 weeks
Passion fruit	7–10	85–90	3–5 weeks
Peach	0	95–98	2–4 weeks
Peppers	7–10	90–95	2–3 weeks
Potato	3–4.5	90–95	5–8 months
Strawberry	0	90–95	5–7 days
Sweet corn	0	90–95	5–7 days
Sweet potato	13	90	6–12 months
Tomato, pink	9–10	85–95	7–14 days
Turnip	0	95	4–5 months
Watermelon	10–15.5	90	2–3 weeks
Fish	0–3	90	1–3 days
Meat	0–3	90	2–7 days
Milk	4		3–5 days
Cooked food			
Vegetables	0–4		2–4 days
Fish	0–4		2–3 days
Meat	0–4		3–5 days
Soup	0–4		2–3 days

temperature and relative humidity in the time of evaporative cooling and their effect on the shelf life of some fruits and vegetables are represented in Table 5.4.

In addition to this, a number of researchers have done extensive research on evaporation cooling to evaluate their effect on shelf life. A list has been extensively represented in Table 5.5.

Table 5.3 Storage life of different categories of food [27]

Shelf life	Foods
1–3 years	Yeast at room temperature Peanut butter Nuts
3–5 years	Vegetable oil and shortening Drink mixes Hot cocoa Coffee Brown rice Peanut butter powder Home or commercially canned fruits, vegetables, and meats
5–7 years	Powdered eggs Butter powder Bullion Yeast stored in a freezer Brown sugar Barley
10 years	White flour Sour cream powder Textured vegetable protein (TVP) product Shortening powder Cheese powder
20 years	Dehydrated fruits and vegetables Freeze-dried cheese Powdered milk Dehydrated carrots Quinoa Rye
25 years	Freeze-dried fruits, vegetables, and meats Instant beans
30+ years	Dry beans, lentils, rolled or whole oats, pearled barley Pasta, potato flakes, cocoa powder White rice, corn Wheat
Indefinite	Sugar Honey Salt Baking powder Baking soda Cornstarch

There would be no significant deviation in the shelf life extension in the variation unless there is variation of the abovementioned factors. Therefore, the required conditions need to be maintained to attain the best performance of evaporation cooling.

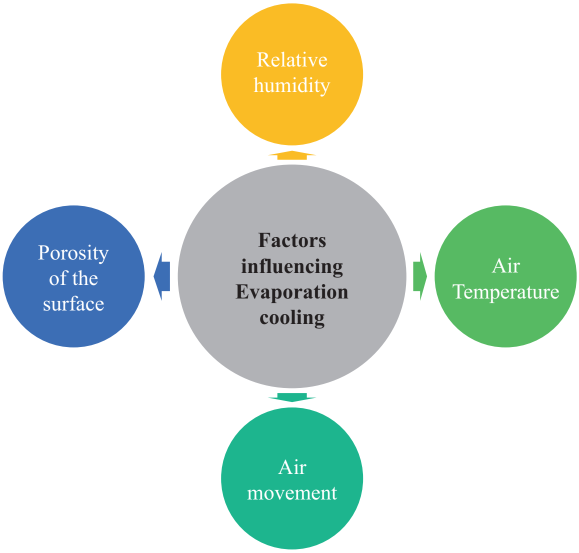

Fig. 5.5 Factors influencing evaporation cooling

Table 5.4 Storage temperature, relative humidity, and shelf life of some fruits and vegetables [28]

Commodity	Storage temperature (°C)	Relative humidity (%)	Shelf life
Asparagus	0–2	95	2–3 weeks
Beans	5–7	90–95	7–10 days
Carrot	0	90–95	2–5 months
Cauliflowers	0	90–95	2–4 weeks
Cucumbers	7–10	90–95	10–14 days
Cabbage	0	90–95	3–6 weeks
Pepper	7–10	90–95	2–3 weeks
Courgettes	0–10	90	5–14 days
Eggplants	7–10	90	1 week
Melons	0–4.4	85–90	5–14 days
Okra	7–10	90–95	7–10 days
Onion (dry)	0	65–70	1–8 months
Potatoes (white)	5–10	93	2–5 months
Potatoes (sweet)	12–16	85–90	4–6 months
Tomato (ripe)	7–10	85–90	4–7 days
Tomato (green)	12–20	85–90	1–3 weeks
Watermelons	4.4–10	90	2–3 weeks
Apples	1–4.4	85–90	3–8 months
Avocados	4.4–12.5	85–90	2–4 weeks
Mangoes	12	85–90	2–3 weeks
Pineapples	7–12.5	85–90	2–4 weeks
Pawpaw	7.0	85–90	1–3 weeks
Carnations	0–2	90–95	3–4 weeks

Table 5.5 Performance of evaporative cooler for different agricultural products [29]

Author	Agricultural product	Performance	References
Maini et al.	Potato tubers	Stored more than 5 weeks in evaporative cool storage compared with normal room temperature	[30]
Chouksey et al.	Onion	Onion could be stored from July to November with proper ventilation	[31]
Roy and Khurdiya	Leafy vegetables tinda, chili, Kerala (Bitter-guard), bhindi, radish, beet, carrot, turnip, peas, cauliflower	The shelf life of leafy vegetables increased to 3 days with PLW of 13–18% For other vegetables, the shelf life was increased to 6 days with 5–6.8% PLW	[32]
Singh et al.	Grapes	PLW was higher at room temperature storage as compared to the zero energy cool chamber under different treatments	[33]
Thingu et al.	Tomato	Evaporative cooled storage showed 100% ripening index, double lycopene content, and less shrinkage as compared to the control sample	[34]
Umbarkar et al.	Orange	Shelf life up to 32 days with less qualitative loss and PLW	[35]
Reddy and Nagaraju	Sapota	The shelf life of sapota fruit cv. Kalipatti increased with reduced PLW and shriveling, higher firmness, and less rotting leading to the recovery of a higher percent of marketable fruits	[36]
Garg et al.	Tomato	The tomato could be stored up to 50 days in EC storage, 32 days in passive draft EC storage, and 30 days in farm-level storage as compared to 14 days in ambient storage	[29]
Pal et al.	Kinnow mandarins	Shelf life increased up to 40 days in EC chamber as against 15 days at room temperature	[37]
Kumar and Gupta	Potato	Potatoes could be safely stored up to 13th week of storage in EC storage as against 8th week in ambient storage without shrinkage and sprouting	[38]
Wasker and Roy	Banana	Banana fruit cv. Basrai could be stored up to 20 days as against 14 days at room temperature	[39]
Dash and Chandra	Economic feasibility	EC structures could be adopted in places where cold storage facilities are not available or the transportation cost to the cold storage is very high to offset the advantages of keeping produce in cold storage	[40]
Bhardwaj and Sen	Mandarin (Nagpur santra)	Mandarin fruit with neem extract treatment could be stored up to 42 days for retaining postharvest quality	[41]
Dhemre and Wasker	Mango	Kesar mango fruits with wax treatment could be stored up to 25 days as against 20 days at room temperature	[42]

(continued)

Table 5.5 (continued)

Author	Agricultural product	Performance	Refere-nces
Mordi and Olorundu	Tomato	Fresh tomatoes could be stored for 11 days as against 4 days at ambient temperature, whereas tomatoes treated with film packaging could be stored for 18 days as against 13 days under ambient condition while completely sealed sample for 8 days as against 6 days under ambient condition	[43]
Singh and Satapathy	Bitter gourd, capsicum, tomato, cauliflower, pineapple, peach	The shelf life of bitter gourd, capsicum, and cauliflower was increased for 5 days, whereas shelf life of tomato, pineapple, and peach increased for about 6–9 days under evaporative storage as compared to ordinary room condition	[44]
Jha et al.	Potato, kinnow, tomato	Safe storage period was found to be 50, 25, and 4 days for potato, kinnow, and tomato, respectively, with 10% loss in weight	[45]
Mishra et al.	Potato, tomato	The shelf life of potato was observed 60 days as against 30 days in ambient storage, while tomato was safely stored for 14 days as against 7 days at ambient condition	[46]
Tilahan et al.	Economic feasibility	The evaporative cooling system was capable of significantly ($P < 0.001$) reducing the temperature and significantly ($P < 0.001$) increasing the relative humidity as required for short-time storage of selected fruits and vegetables such as carrot, mango, papaya, banana, mandarin, orange, lemon, and tomato	[47]
Chinenye et al.	Tomato	The evaporative cooled storage was able to preserve freshly harvested tomato for 19 days	[48]
Mogazi and Fapetu	Tomato, carrot	The shelf life of tomato and carrot was extended by 14 days relative to ambient storage	[49]
Samira et al.	Green pepper	The shelf life of green pepper was effectively improved 20 days as compared to storage under ambient condition	[50]

1.6 Steeping

In steeping, sodium chloride acts as a preserving, flavor-improving, conditioning, and taste-enhancing agent. After leaching out the salt and acid, the preserved vegetables, by steeping, may be used for pickling or home cooking. The animal-based foods like meat, fish, and poultry; vegetables such as tomatoes, carrot, cauliflower, cabbage, bitter gourd, peas, and mushroom; and fruits like green mango, olive, and golden apple can be preserved in an acidified sulphited brine solution [51, 52].

Due to the diversification of structural and compositional nature of food material, shelf life extension varies between types of food materials. For example, button mushrooms have a very shorter shelf life of 3–4 days. They lose their commercial value within a shortest possible time due to browning, water loss, senescence, and microbial attack. But due to the introduction of the steeping process, the shelf life of this product exacerbates significantly [53]. To enhance the shelf life as well as to improve the pH, color, antioxidant potential, and microbial flora of mushrooms, the steeping process is accomplished [54]. Steeping of mushrooms increases the shelf life for up to 80 days. Similarly, cauliflower was in an acceptable condition even after 80–90 days of storage [55]. Moreover, Pruthi et al. [56] detected that diverse vegetables such as carrot, mushrooms, potatoes, cabbage, and peas and animal food (meat, fish, and poultry) may be well-preserved in acidified sulphited brine solutions through steeping to a considerable extent of time period.

Similarly, salting extends the shelf life significantly. However, most of the cases salting comes with other food preservation techniques such as drying, roasting, and smoking. Salt basically hinders microorganisms by reducing water activity of food materials. The extension of shelf life depends on the concentration and proper distribution of salt on foods.

1.7 Chilling

By reducing the temperature, all the processes are restricted to a considerable extent which improves the shelf life of food materials significantly. Chilling accomplishes the same thing by reducing the rate of this reaction. For example, by using chilling process, tilapia may be retained for 28 days, and Indian major carp, rohu, can be kept for 35 days. Maitta and surma (mackerel) may be preserved for almost 9–15 days. In addition, *hilsa* (river shad) may be retained for at least 15–17 days [57].

Similar to chilling, the method of superchilling also contributes to the enhancement of the shelf life significantly. Superchilling is one of the low-temperature preservation systems that maintains a lower temperature than freezing temperature. Superchilling is more feasible for certain foods over refrigeration and freezing, eventually decreasing storage and transport costs [58]. The key benefit of this technique of preservation above outdated approaches is that it upsurges the shelf life of food materials especially meat for up to 4 times [58]. Superchilling prolongs the shelf life of stored food materials at least 1.5–4 times compared to conventional chilling [59]. Table 5.6 reveals the effect of superchilling in the shelf life of different selected food materials [60].

Shelf life of superchilled food varies between types of foods. However, the ice quality significantly affects the cooling pattern during superchilling process. Many a time, improper distribution of ice causes relatively lower lengthening of shelf life of food materials in developing countries. Moreover, ice melting factors need to be controlled in all possible ways to retain a consistent cold environment in the superchilling system.

Table 5.6 Effect of superchilling in the shelf life of different selected food materials [60, 61]

Product	Superchill temperature (°C)	Packing atmosphere	Shelf life extension (days)
Salmon	−1.5	90% CO_2	11
Mullet	−2.0	Vacuum	3
Japanese sea bass	−1.5	40% CO_2/30% CO_2	4
Cod muscle	−4.0	Air	5
Pork roast	−2.0	Air	98
Salmon	−1.4	Air	17
Salted fresh salmon	−1.0	Air	7
Salmon	−2.0	60% CO_2	11
Cod fillet	−1.5	Air	3
Japanese sea bass	−3.0	Air	14
Cod	−2.0	60% CO_2/5% O_2	7
Wolf fish	−1.0	60% CO_2	2
Arctic char	−2.0	CO_2	6
Shrimp	−3.0	Air	6

1.8 Freezing

Freezing is a low-temperature technique that prevents the production of microorganisms. Besides that, chemical reactions are reduced, and cellular metabolic reactions are hindered by freezing [62].

In freezing, the combined effect of reduced temperature and reduced moisture levels is implemented that results in higher quality of frozen food and thereby ensures exacerbated shelf life [63]. Researchers have experimented on some effects of freezing on the shelf life of food materials. Some examples of the positive effects on the shelf life of food materials are discussed here.

Perez-Chabela and Mateo-Oyague have found that the shelf life of vacuum-packaged fresh beef is almost 35–45 days, whereas refrigeration at a temperature of 0–2.3 °C provides longer shelf life of approximately 70–80 days [64]. Delmore found that frozen whole-muscle beef has an extended shelf life of 12 months [65]. Perez-Chabela and Mateo-Oyague established that the shelf life of red meat kept at 15–30 °C generally varies from 6 to 24 months [64, 66]. The shelf life of fillets extends from 11 to 14 days in cold storage if coated with alkaline-treated protein (AlPC) and acid-treated protein (AcPC) [67]. Moreover, Table 5.7 designates particular recommended practical storage lives for numerous food commodities at different frozen storage conditions.

Table 5.7 Practical frozen storage lives (months) for various foods [63]

Product	Frozen storage temperature		
	−12 °C	−18 °C	−24 °C
Fruits			
Strawberries/raspberries	5	24	>24
Peaches/apricots	4	18	>24
Fruit juice concrete	–	24	>24
Vegetables			
Asparagus	3	12	>24
Beans, green	4	15	>24
Beans, lima	–	18	>24
Broccoli	–	15	>24
Brussels sprouts	6	15	>24
Carrots	10	18	>24
Mushrooms	2	8	>24
Peas, green	6	24	>24
Potatoes	9	24	>24
Spinach	4	18	>24
Meats and poultry			
Beefsteaks	8	18	24
Beef ground	6	10	15
Lamb steaks	12	18	24
Pork steaks	6	10	15
Chicken, whole	9	18	>24
Chicken,cuts	9	18	>24
Turkey,whole	8	15	>24
Ducks/geese whole	6	12	18
Fish and seafoods			
Fatty fish	3	5	>9
Lean fish	4	9	>12
Lobster, crabs, shrimps (in shell, cooked)	4	6	>12
Clams and oysters	4	6	>9
Shrimps, peeled and cooked	2	5	>9

1.9 Drying

Drying is an ancient food preservation technique. It is still one of the dominating food preservation techniques that are practiced in developing countries across the globe. Most of the raw food materials are high in water content and make it susceptible for the growth of microorganisms. Drying is basically a water-removing process where simultaneous heat and mass transfer take place. In addition to prevention of microorganisms, drying offers ease in handling, packaging, shipping, and consumption. Drying increases the shelf life of food materials to an appreciable extent

Table 5.8 Effect of shelf life on the drying of different selected foods [68]

Products	Shelf life (years)
Brown rice, butter and margarine powder, garden seeds, granola, yeast	1–5
Gluten, powdered and whole eggs, white flour	6–10
All-purpose flour, cheese powder, cocoa powder, flax, noodles, soybeans, TVP, unbleached flour, whole-wheat flour	11–15
Alfalfa seeds, baker's flour, corn, cracked wheat, potatoes (all), quinoa sprouting seeds	16–20
Apple, black turtle beans, Black-eyed beans, broccoli, buckwheat, cabbage, carrots, celery, cornmeal, fruit, garbanzo beans, great northern beans, kidney beans, lentils, lima beans, macaroni, onions, peppers, pink beans, pinto beans, powdered milk, refried beans, small red beans, spaghetti	21–25
Adzuki beans, barley, germade, groats, hard red wheat, hard white wheat, hulled oats, kamut, millet, popcorn, rolled oats, rye, soft wheat, spelt, triticale, white rice	26–30
Honey, salt, and sugar	∞

that is represented in Table 5.8. It is worthy to mention that the shelf life presented of dried food is subject to preserve in a proper storage conditions.

2 Quality

Food quality consists of psychological factors, impressible properties, and also some other features like contributions to health and balancing the lifestyle situation [69, 70]. Figure 5.6 represents the classification of food quality attributes. If any of the property or value is lost at the optimum stage, then it becomes inconsumable in many cases.

Therefore, the preservation techniques that can sustain these quality attributes for a longer period of time can be considered as effective food preservation techniques. It is complex to summarize the quality aspect of foods that are preserved in developing countries. A wide range of effects may occur throughout the different storage techniques of food that can substantially affect the nutritional content of the preserved food. Moreover, the rate of change in nutritional, physiochemical, and structural aspects varies differently in individual preservation technique.

Many factors contribute in the degradation of the quality aspect of food material during preservation. The selection of raw materials, pattern of transportation, preparation for preservation, technique of preservation, and condition of preservation cause significant contribution in the kinetics of chemical reaction, heat and mass distribution, and structural imprint.

Figure 5.7 shows the effect of different food preservation techniques on the nutritional quality of preserved food [71].

To be more specific, Table 5.9 shows the average value of degradation of nutritional values of food during different food processes including drying, cooking, reheating, and freezing.

Fig. 5.6 Classification of food quality attributes

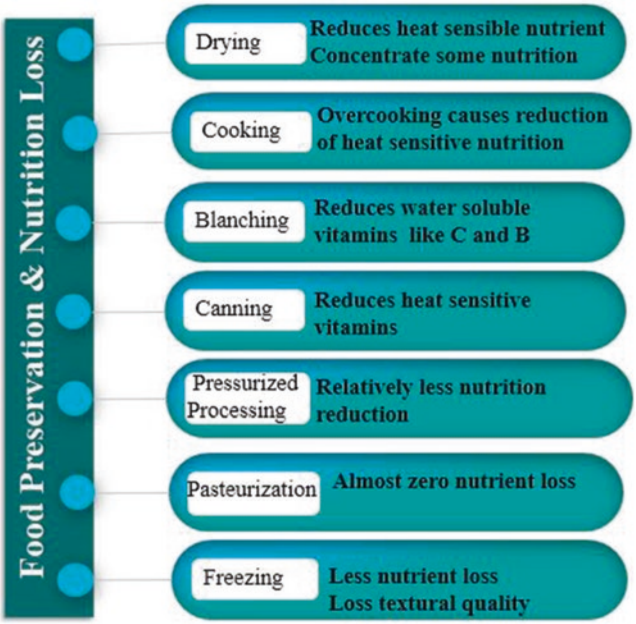

Fig. 5.7 Effect of different food preservation techniques on the nutritional quality

Table 5.9 Typical nutrient losses due to processing as compared to raw food [50, 72]

	Freeze (%)	Dry (%)	Cook	(Cook + drain)	Reheat
Vitamins					
Vitamin A	5	50	25	35	10
Retinol activity equivalent	5	50	25	35	10
Alpha carotene	5	50	25	35	10
Beta-carotene	5	50	25	35	10
Beta cryptoxanthin	5	50	25	35	10
Lycopene	5	50	25	35	10
Lutein + zeaxanthin	5	50	25	35	10
Vitamin C	30	80	50	75	50
Thiamin	5	30	55	70	40
Riboflavin	0	10	25	45	5
Niacin	0	10	40	55	5
Vitamin B6	0	10	50	65	45
Folate	5	50	70	75	30
Food folate	5	50	70	75	30
Folic acid	5	50	70	75	30
Vitamin B6	0	0	45	50	45
Minerals					
Calcium	5	0	20	25	0
Iron	0	0	35	40	0
Magnesium	0	0	25	40	0
Potassium	0	0	25	35	0
Sodium	10	0	30	70	0
Sodium	0	0	25	55	0
Zinc	0	0	25	25	0
Copper	10	0	40	45	0

Almost all the food processing technologies reduce the percentage of nutrients in food. The techniques especially work where a high level of heat, oxygen, or light is required and causes a significant amount of nutrient loss. In many cases, nutrients may be "washed out" by the fluids that are utilized during a cooking process. However, the table demonstrates the general trends, not for individual cases. The variability of nutrition varies with different factors as mentioned beforehand.

Similar to nutritional values, other quality attributes degrade distinctly in different preservation techniques. Figure 5.8 demonstrates the effect of dissimilar preservation method on different selected nutritional properties that was experimented on mushroom by Reid et al. [73]. The study shows that if the preservation techniques are appropriate by maintaining all the process parameters required for the technique, they will be able to sustain all the nutritional value to an appreciable range. In this study, preservation was observed to have a positive impact on the nutrient and phytochemical composition of the mushrooms. In all cases, the preservation technique displays a positive result in maintaining the nutritional values.

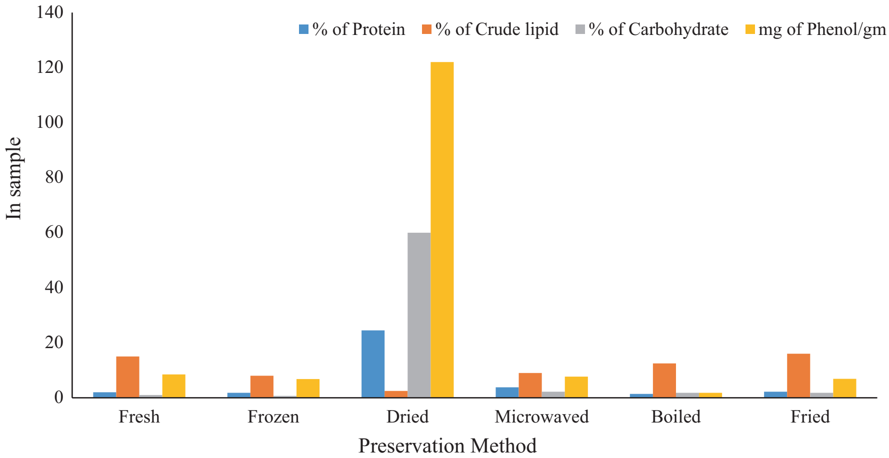

Fig. 5.8 Effect of dissimilar preservation method on different selected nutritional properties [73]

However, there are some fluctuations that are demonstrated, but overall if the techniques are properly implemented, then it is possible to ensure a highly processed quality preserved food in terms of nutritional properties.

Moreover, prediction of quality degradation becomes harder due to the diversification between samples of the same kind. For example, Hosain et al. [74] investigated the storage characteristics of okra pickles to evaluate the quality attributes of okra pickles after a certain time. To do this he has selected three different samples, and every single pickle was used for storage studies at room temperature (27–33 °C) from 0 to 5 months. The effect of storage time (0, 1, 2, 4, and 5 months) on the change in physical properties such as flavor, texture, and color of the pickles is represented in Table 5.10.

The preservation technique would be inconsequential if the food does not retain qualitative values anymore. Therefore, all the processes that undergo through high levels of heat, light, or oxygen cause an extreme amount of nutrient loss. In order to keep the quality of processed foods close to fresh ones, high scrutiny of the factors affecting quality negatively must be taken into account.

3 Cost

An effective food preservation system should be capable of minimizing the cost of preservation by ensuring high-quality preserved food. There are different food preservation systems that require a wide range of cost. However, the cost of an effective system basically depends on some factors which are represented in Fig. 5.9.

Table 5.10 Storage studies of okra pickles [74]

Storage period	Sample code	Color	Flavor	Texture	Visual fungal growth	Remarks
0	101	No change	No off-flavor	Firm	No growth	Good
	202	No change	No off-flavor	Firm	Do	Good
	303	No change	No off-flavor	Firm	Do	Good
1	101	No change	No off-flavor	Slightly soft	Do	Good
	202	No change	Off-flavor	Slightly soft	Do	Good
	303	No change	No off-flavor	Slightly soft	Do	Good
2	101	No change	No off-flavor	Soft	Do	Good
	202	Change	Off-flavor	Slightly soft	Do	Good
	303	No change	No off-flavor	Soft	Do	Good
3	101	No change	No off-flavor	Soft	Slight growth	Good
	202	Change	Off-flavor	Slightly soft	Do	Slightly good
	303	No change	No off-flavor	Soft	Do	Good
4	101	No change	No off-flavor	Extremely soft	Slight growth	Good
	202	Change	Off-flavor	Slightly soft	Excessive growth	Spoiled
	303	No change	No off-flavor	Extremely soft	Slight growth	Slightly spoiled
5	101	No change	No off-flavor	Extremely soft	Slight growth	Good
	202	Change	Off-flavor	Slightly soft	Excessive growth	Spoiled
	303	No change	No off-flavor	Extremely soft	Slight growth	Slightly spoiled

3.1 Inefficient Use of Energy

Food processing, food transport, storage, and cooking are all parts of a comprehensive food system. A comprehensive food system is not only restricted to the farm-level production alone. The trend of consuming energy in the food processing and storage stage is more than a few times greater than farm-level actions. By analyzing different selected countries over the world, it has been found that the total food

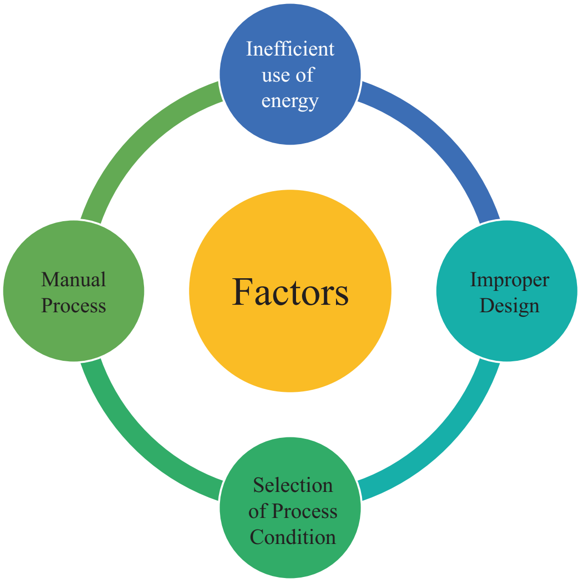

Fig. 5.9 Factors on which cost of food preservation depends

system consumes about 17–20% of the total energy use of a country [75]. Among the total consumed energy, typically about one-fifth to one-quarter is used by the production stage, and the remaining portion is utilized for the postharvest operations such as processing or storage.

As a substantial amount of energy is used by the postharvest food preservation technologies, therefore efficient use of the energy is obvious. There are some traditional systems that consume higher extent of energy and produce low quality of preserved food. Hence, to become an effective food preservation system, it is compulsory to use the energy efficiently that is required to run the system.

Different factors including process parameters, energy efficiency of the preservation system, as well as types and grade of energy significantly affect the amount of energy consumption. In developing countries, lower grade of energy and less efficient devices cost higher amount of energy.

3.2 Improper Design

Systems design is the process of defining the modules, interfaces, and data for a system to content specified requirements. Different systems have different criteria for the appropriate design so that it can be run effectively. In the same way the design of an efficient food preservation system has also some specified criteria on the basis of which the system has to be designed. However, the designed criteria are varied from system to system. The principal design criteria for ensuring higher shelf life and higher-quality preserved food products are temperature, airflow, humidity of the air, and light. Moreover, every preservation system has their unique criteria to construct it upon which the effectiveness of the specific system is fully dependent.

3.3 Selection of Process Condition

In the present era, the highest concern for consumers is the wastage of food either in the form of microbiological or chemical origin. Food conditioning is the main area of food wastage if all the process condition for the specific food process is not maintained. Storage of raw materials, preheating, disinfection, cleaning, and sterilization steps are the main steps of food conditioning. For every system there are specific process conditions; if those are not followed, then food contamination can occur which will finally lead to wastage of food. For example, in the case of drying, Tzempelikos et al. have found that an increase from 40 °C to 60 °C, at 2 ms^{-1}, resulted in a decrease of the total time of drying of 54% and an increase from 1 ms^{-1} to 2 ms^{-1}, at 60 °C, resulted in a decrease of the total time of drying of about 30% [76]. If these process conditions are not optimized, then that will put impact on the required energy, and as a consequence finally the effectiveness of the system will be hampered. In a similar way, all the preservation system has some conditions which must be maintained to offer an effective food preservation system.

3.4 Manual Process

In the developing world the trend of using manual process to preserve the food is very high. However, the problem is in manual process the required time to process the food is high as well as the quality of the preserved food quality is also low. On the other hand, automated machine took less time. Consequently, lower running cost is ensured by the techno-based devices. However, the installation cost is pretty much higher than the manual setup. After optimization of different costs, the manual preservation practiced in developing countries cost relatively higher.

3.5 Types of Process

Apart from the abovementioned parameters, overall cost varies between types of food preservation techniques (Table 5.11). The demand of energy, processing time, and governing physics vary significantly between processes. In order to compare the associated cost of different causes, Table 5.11 shows the cost of different food preservations including freezing, canning, drying, and smoking [76].

Table 5.11 Cost of preserving 1 pound of food (not including the cost of the food) for 1 year by different selected methods at seven cooperative extension districts during the summer of 2009 [76]

	Alaska districts	Anchorage	Bethel	Fairbanks	Juneau	Kenai	Nome	Palmer
Total cost to preserve pound of food in 1 year by	Manual defrost chest freezer	$0.65	$1.03	$0.86	$0.45	$0.78	$1.01	$0.73
	Water bath canning/jarring (14 pins jars)	$0.79	$1.41	$1.02	$0.85	$0.87	$1.19	$0.82
	Water bath canning/jarring (56 pins jars)	$0.49	$1.11	$0.73	$0.56	$0.58	$0.90	$0.53
	Water bath canning/jarring (7 pins jars)	$0.67	$1.34	$0.92	$0.71	$0.77	$0.10	$0.71
	Water bath canning/jarring (49 pins jars)	$0.48	$1.15	$0.73	$0.53	$0.58	$0.92	$0.52
	Food dehydrators (420 W)	$0.06	$0.09	$0.08	$0.03	$0.08	$0.11	$0.07
	Food dehydrators (490 W)	$0.07	$0.11	$0.10	$0.04	$0.10	$0.12	$0.08
	Smoking by *LittleChief/250 W*	$0.04	$0.06	$0.05	$0.02	$0.05	$0.06	$0.14
	Smoking by *Big chief/450 W*	$0.007	$0.10	$0.09	$0.04	$0.09	$0.11	$0.08

From Table 5.11, it is clearly depicted that the costs of the food preservation techniques vary with each other. The nature of process and intensification of process parameters are the determinant of the overall cost of preservation.

In a nut shell, the effectiveness of the preservation techniques practiced in developing countries is subject to different factors including the types of process, nature of energy, efficiency of the system, and skill of the people. Traditional food preservations offer many advantages including low initial and maintenance cost, easy fabrication, and easy maintenance. On the other hand, traditional preservations regularly encounter many challenges. Taking the quality of preserved foods, energy consumption, cost, as well as processing time into consideration, there is a huge scope of improvement of the effectiveness of the food preservation that takes place in developing countries.

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Chapter 6
Harmful Side Effects of Food Processing

Abstract Any process-associated food preservation deteriorates overall quality of food materials to some extent. Many a time, improper preservation practices result in harmful effects on foods. Contamination can be accessed through different pathways including biological, chemical, as well as physical ones. Improper process conditions, processing environment, wrong ingredient, and improper balance of processing components may cause mild to severe contamination in food materials over the time of preservation process. Out of the contaminations, excess chemical preservation and proliferation of microorganisms lead to severe negative health consequence. Proper hygiene practices, leaving harmful preservatives, and maintaining required preservation conditions would ensure the safe quality of preserved foods. In this chapter, the potential ways of food contamination have been discussed in details.

Food contamination can be described as the presence of harmful chemicals and microorganisms in foods that may cause consumer illness. Therefore, it is significant to comprehend what the possible hazards are when it comes to food safety. Food can be contaminated in many ways, namely, physical, biological, or chemical. It mainly refers to food that has been degraded with a different foreign constituent—physical, biological, or chemical. All the sources of contamination along with its short description are revealed in Fig. 6.1.

However, all the food preservation approaches do not undergo within all types of contamination in the same degree or simultaneously. In this chapter, the contamination occurrences associated with the common food preservation systems in developing countries are discussed.

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Fig. 6.1 Sources of contamination in food

1 Transportation

In the food supply chain, transportation plays a significant role that serves market accessibility to all goods including fresh and processed foods by linking the consumers and producers [1]. Transportation has a direct association of food cost, delivery time to customer, as well as maintenance of food quality [2]. Moreover, transportation enhances the interaction between economic and geographical regions as well as the development of the market for agricultural production. Unlike the modern transportation of developed countries, there is a very poor condition persisting in the transportation system in developing countries.

Food contamination may occur over the course of transportation. Because of the vehicle exhausts from petrol and diesel or for a cross-contamination in the vehicle used for food transportation, contamination of food may occur. This cross-contamination might generate a severe hazard for food safety. The European Economic Community suffered from a major illness in 1999 due to the fungicide-contaminated pallets used for transportation and storage of food packaging materials. Cross-contamination also occurs several times in the long-distance transportation when the chemicals are used for disinfection or from new sources [3].

In the time of long-term transportation such as shipping, the high obstruction materials are used for wrapping and protecting the food. However, there is a high potential of organic compound contaminations, as only permanent gases such as O_2 and CO_2 and water vapor permeation are commonly checked [4].

2 Smoking

In the recent time, smoking methods are usually done to pre-salted, entire, or filleted fish. Smoking is typically accomplished with wood smoke, and usually smokes from incompletely burnt wood come in direct contact to foods. However, if the method is not satisfactorily controlled or there is presence of excessive smoke, there is a huge chance for the product to be contaminated with polycyclic aromatic hydrocarbons (PAHs) [1, 2]. PAHs are usually generated as a consequence of incomplete combustion or thermal decomposition of the organic materials [6].

There are substantial health effects comprising of mutagenic, carcinogenic, and teratogenic that might happen during the smoking process because of some unwanted chemical reactions. The health-threatening substances formed due to smoking are represented in Fig. 6.2 [7].

The closeness of the food to the heat source and the fat content of the food significantly affect the PAH production during the cooking of food over charcoal (barbecued, grilled) [4, 5]. The presence of PAHs, for instance, benzo[α]pyrene, anthracene, chrysene, benzo[α]anthracene, and indeno[1,2,3-c,d]pyrene, is found from the numerous investigations of charcoal-roasted/charcoal-grilled common fish [8–11]. Most of these PAHs have been found to be carcinogenic [12–15]. In addition, the PAH content by the smoked food found by numerous researchers is presented in Table 6.1.

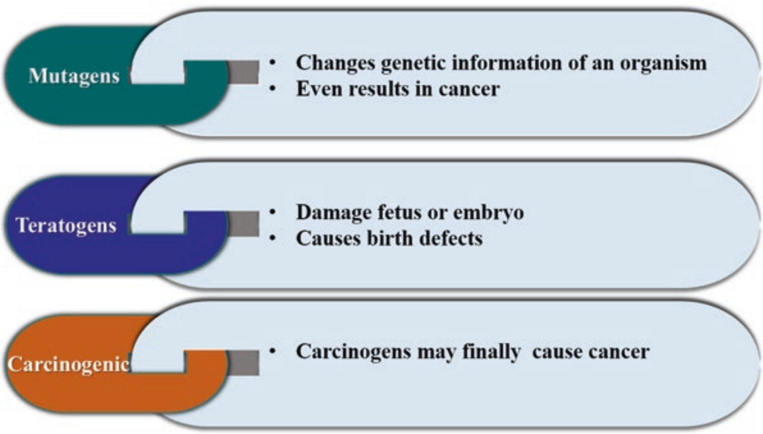

Fig. 6.2 The health-threatening substances formed due to smoking

Table 6.1 PAHs content by the smoked food

Year	Author	Remarks	Reference
1982	Emerole et al.	Reported that appreciable amounts of benzo[α] anthracene and benzo[α]pyrene are present in three varieties of smoked fish and smoked meat (suya)	[16]
1998	Ova and Onaran	PAH levels were significantly higher in the fish skins than in the edible parts	[17]
2006	Adebayo-Tayo et al.	Reported the presence of aflatoxin B1 and G1 in high concentrations in fish and concluded that smoked dried fishes stored for sale in Uyo markets, Nigeria, were heavily contaminated with aflatoxigenic fungi	[18]
2011	Olabemiwo et al.	Reported that the sum of all PAHs in the smoked fish (*Clarias gariepinus* and *Tilapia guineensis*) ranged from 0.497 to 0.814 μg/kg and 0.519 to 0.772 μg/kg, respectively	[19]
2006	Adebayo-Tayo et al.	Reported the presence of aflatoxins; highly toxic compounds naturally produced by *Aspergillus flavus*, *Aspergillus parasiticus*, and some *Aspergillus microsclerotial* in fish and fish feed	[14, 16, 17]
2011	Almeida et al.		
2013	Barbosa et al.		
1990	Jantrarotai and Lovell	Reported the hazardous effects of aflatoxin-contaminated feeds on fish health and production have been documented	[20–24]
2000	Hussein et al.		
2003	Shehata et al.		
2007	Abdelhamid et al.		
2008	Zaki et al.		
2015	Adeyeye et al.	Reported that the traditional drum-smoked samples had high BαP and PAH levels (five out of six major PAHs [fluorene, anthracene, benzo(β)fluoranthene, benzo(α)anthracene, benzo(α)pyrene, and benzo(ghi)perylene] exceeded the EU maximum permissible level of 5.0 μg/kg for BαP)	[25]

3 Salting

Salted fish and salt-cured meat are very common processed foods that are available in almost all of the developing countries due to their simplicity and low cost of processing. However, excess consumption of salt is one of the key elements contributing to hypertension and associated diseases. Hence, the abnormal ratio of K/Na results in the etiology of cardiovascular disease and mortality. An optimal harmless sodium intake of 5 g/day salt and potassium intake of at least 3510 mg/day by adults are recommended by the WHO to ensure a safe life [26, 27].

The usual salt consumption in a maximum of the countries across the world is roughly 9–12 g/day. In the Asian region, the picture is more severe, with having average intakes more than 12 g/day. For the children older than 5 years have a mean

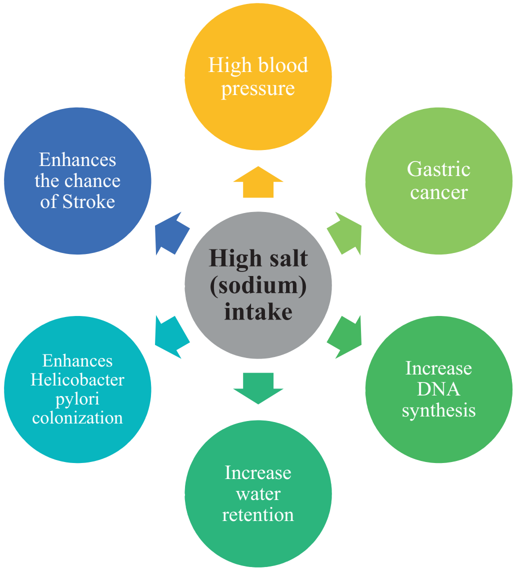

Fig. 6.3 Diseases that may occur due to excessive salt consumption

salt intake of more than 6 g/day [28]. However, in many cases where salting is extensively used as a food preservation technique, the average consumption rate of salt extremely violated from the recommended intake.

This high-salt consumption has been recognized as a public health risk. Owing to this, some studies have been accomplished to diminish the salt rate in the food industry. The dissimilar diseases that may occur due to excessive salt consumption are shown in Fig. 6.3 [29–34].

4 Canning

Canning prevents microorganism growth and inactive enzymes. However, beyond these enormous advantages of canning, it has also some risky sides. Poor manufacture (underprocessed) and poor hygiene permit contamination of canned food by the obligate "anaerobe *Clostridium botulinum*" that generates a serious toxin in the food and leads to extreme illness or death. No noticeable change in taste or smell can be found in the presence of this seriously hazardous microorganism. There are some foods such as cooked mushrooms, if controlled poorly and then canned, which may accelerate the growth of "*Staphylococcus aureus*" that produces a toxin which cannot be destroyed by canning or succeeding heating steps.

During the most primitive days of canning, a number of individuals, including some Arctic explorers, possibly died as a consequence of exposure to the lead that was once used to solder cans. Present approaches use the air removal technique that includes vacuum sealing and the use of plastic wrappings [35]. However, for the

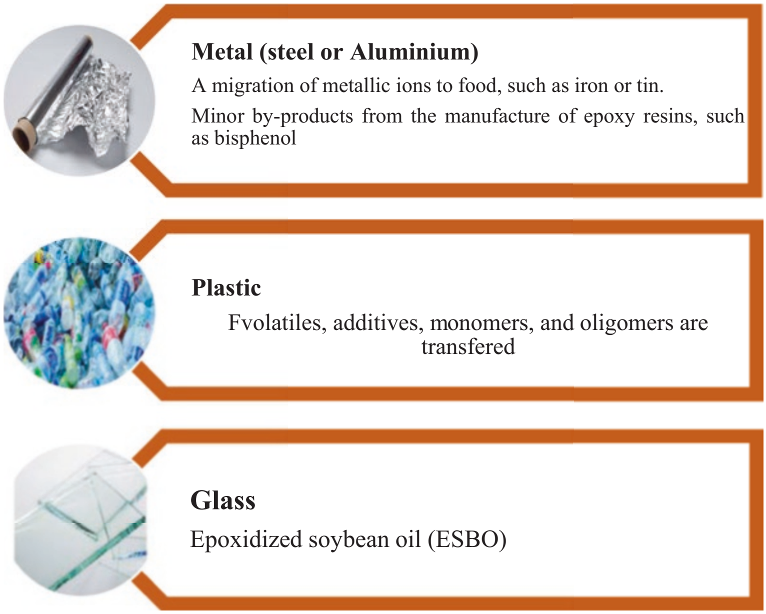

Fig. 6.4 Canning materials as a source of contamination of food [37, 38]

purpose of canning, different types of materials that act as a source of contamination through the migration of substances from the material to the food are represented in Fig. 6.4 [36].

Besides the abovementioned contamination, histamine or scombroid transfer in food materials, especially in fish, is a significant contamination that occurs due to the canning method. Literature shows that histamine cannot be sensed in the fresh fish samples, whereas it can be detected that 44.6% of the canned fish samples contained histamine [4].

Histamine poisoning is the leading cause of foodborne illness, which is encountered frequently as a minor illness with a diversity of symptoms comprising rashes, nausea, diarrhea, flushing, swelling of the face and tongue, headache, dizziness, and hypotension. Moreover, in the literature life-threatening cases have been also reported. The intensity of the symptoms differs depending on intake amount of histamine and the histamine sensitivity of the consumer [39–47].

5 Pickling

Pickling is a type of wet salting where the food is kept submerged in a brine solution. Pickling does not leave the meat as salty as in dry salting, but it still necessitates to be presoaked, which takes away surplus salt, before cooking [37, 38].

If pickling is not conducted properly, pickled vegetables may be a possible source of carcinogen. Moreover, from metadata analysis on pickling, it is found that pickled foods significantly increase the risks of esophageal cancer. Improper pickling also has the potential to increase the danger of esophageal cancer. In addition, from the related literature, it is found a momentous increase in the risk of gastric cancer owing to the extra frequent use of pickled vegetables [33, 34].

6 Fermentation

In food processing, fermentation can be considered as a process in which, using microorganisms like yeasts or bacteria under anaerobic conditions, carbohydrates are converted into alcohol or organic acids [48].

In developing countries, fermentation of food materials is especially used in circumstances where drying is impossible in the absence of sun and in the wet climate.

Fermented foods show the fabulous safety record even in the developing countries where the fermentation is accomplished by individuals who have no training in microbiology or chemistry. However, inappropriately fermented foods can be unsafe for consumption. Moreover, lessening of nutritional diseases and superior resistance to intestinal and other diseases in infants can be ensured by having an overall high-quality fermented food. But the dark side is that inappropriately fermented foods can result in some negative outcome as presented in Fig. 6.5 [49–52].

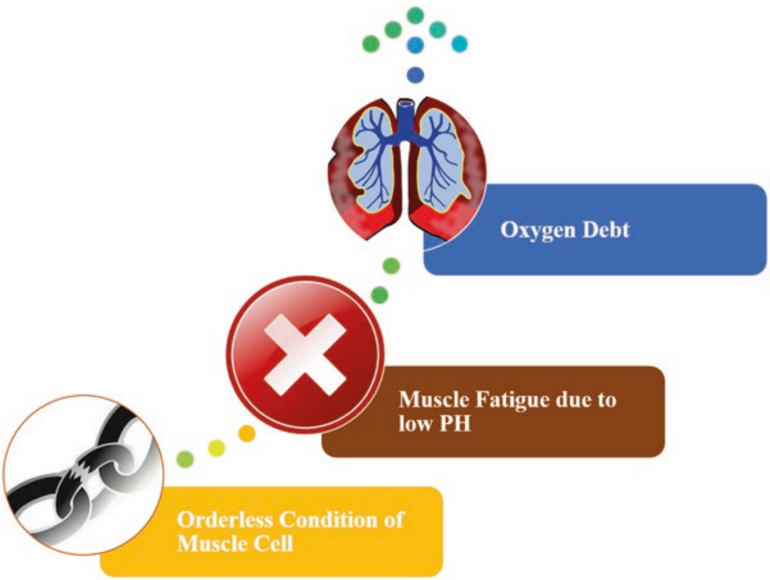

Fig. 6.5 Negative outcomes of consumption of inappropriately fermented foods

7 Curing

This process is basically performed on the foods like vegetables, fish, and meat with a view to receding the moisture content from the foods by the technique known as osmosis [53]. However, there are also some curing techniques in which spicing, cooking, or smoking is done to finally attain the cured food products. Among the different curing agents, nitrates and nitrites, in conjunction with salt, are the most common ones [54, 55].

One of the key concerns related to the extensive use of nitrates and nitrites is mycotoxin, which is a kind of substance that is generally produced in dry-cured meat products. It acts as a contaminated means by which diverse kind of food species may be affected including the genera of *Aspergillus* and *Penicillium*. Moreover, it can also be present in fungal spores and mycelium [56, 57]. There are several potential producers of mycotoxins such as *A. versicolor* (sterigmatocystin, nidulotoxin), *P. brevicompactum* (botryodiploidin, antibiotic mycophenolic acids), *P. chrysogenum* (roquefortine C, PR-toxin, secalonic acids, antibiotic penicillins), *P. nordicum* (ochratoxin A and B, viridic acid), and *P. polonicum* (penicillic acid, verrucosidin, nephrotoxic glycopeptides) [58][56]. Moreover, there is another substance named antibiotics that also negatively affect the food, which can be produced from *P. nalgiovense* (penicillins) and *P. "milanense"* (xanthoepocin) [57]. Therefore, the growth of mycotoxin, as well as antibiotics on the dry-cured food products, creates a prospective health risk for customers [58].

Countries that have very limited resources regarding the health system have to face a substantial amount of difficulties to investigate the effects of mycotoxin on human health. Different researchers have made some contribution to accumulate the effect of mycotoxin on human health that has been represented in Fig. 6.6 [59].

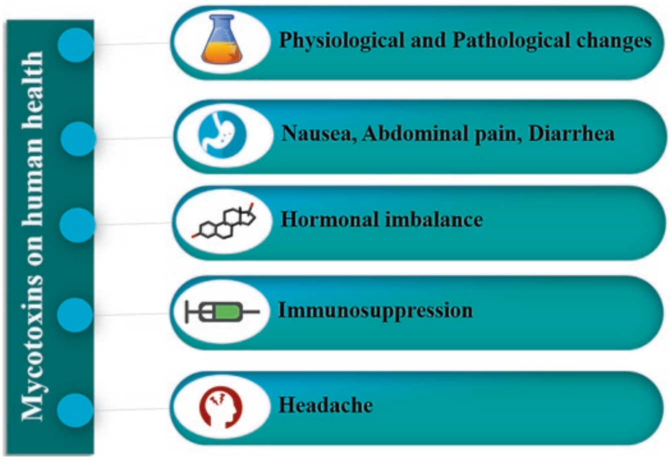

Fig. 6.6 Effect of mycotoxins on human health

8 Drying

Owing to the poor handling during the drying process, dried food may become contaminated with bacteria and/or mold. Perhaps the bacteria or molds may negatively distress the gut as pathogens or probably by just shifting the usual flora of the intestine. Albeit a very lower amount of moisture is present in dried food, they are often affected by harbor bacteria and other microorganisms. *Coliforms*, *Aspergillus*, and *E. coli* were identified in numerous tested dried fruits. Moreover, if foods are dried in open spaces, the item for consumption unusually infected by pests that finally contaminate the dried fish. Proper salting and smoking pretreatment may obstruct the infestation of the pest during the drying process [60]. If infested dried food is consumed regularly, it can create an intestinal upset.

9 Frying

To maintain the quality and the shelf life of fruit alongside having a pretty good market, foods are converted into chips by frying that is basically a dehydration method in which oil acts as the medium for heat transfer. Chips are more long-lasting than the stored fresh fruits or vegetables. This happens because of the low water content, and it no longer requires any physiological processes [61].

Frying food upsurges the fat and calorie consumption in the human body, particularly if frying is accomplished at an excessively low temperature or a large

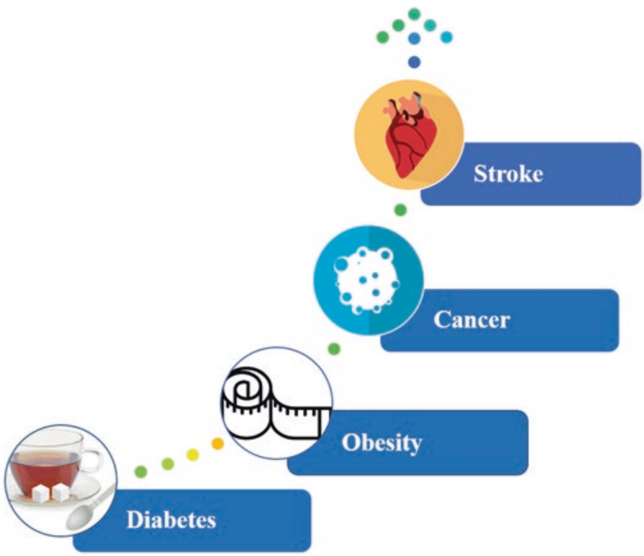

Fig. 6.7 Sickness raised due to the excessive consumption of fried foods

amount of food is fried in the pan at one time. Placing an excessive amount of food in the pan at once drops the temperature of the oil that consequently raises the extent of time it requires to fry the food. Finally, because of this issue, the amount of absorbed fat and calorie in the fried food is exacerbated in a significant manner. For the period of the interaction of frying fat and protein, a substantial amount of mutagenic polycyclic aromatic heterocycles are generated.

Moreover, numerous composites are released from the food into frying oil, increasing discoloration or off-flavors. In addition, salty food releases chlorophenol fatty acid esters and the related substances to the oil during frying. Owing to high fat and calorie content in fried food, excessive consumption of fried food result in frequent health complications [62]. Figure 6.7 illustrates increase of different sickness that may be developed due to the excessive consumption of fried foods [63]. Cristina Nerín, Margarita Aznar, Daniel Carrizo."Food contamination during food process",Trends in Food Science & Technology, 2016.

10 Storage

Plant-based food materials such as fruits, vegetables, and grains are treated as living tissue [64, 65]. However, the detachment eventually leads them toward degradation of quality if preserved in an inappropriate condition [66–68]. Also, a specific amount of oxygen, carbon dioxide, and moisture is required to keep the fruits, vegetables, and grains fresh [69, 70]. The cellular breakdown is normal and inevitable for

Table 6.2 Appropriate storage time period of some selected fruits, vegetables, and grains

Commodities	Storage time period	Example
Fruits	1–7 days	Blackberries, dewberries, raspberries, strawberries
	1–8 weeks	Apricot, mangoes, blueberries, currants, elderberries, gooseberries, cherries, grapes, peaches, quinces, guava, limes, lychees, nectarines, olives, orange, papayas, pineapples, plums and prunes, tangerines, banana
	1–12 months	Apple, cranberries, coconut, dates, pears, lemons, pomegranates
Vegetables	3–14 days	Green beans, lima beans, beets, broccoli, chard, collards, corn, cucumbers, greens, mushrooms, okra, spinach
	1–6 weeks	Asparagus, Brussels sprouts, cabbage, cauliflower, chicory, kale, lettuce, casaba, crenshaw, honeydew, Persian, watermelon, peas, sweet peppers, radishes, rhubarb, watercress, squashes, tomatoes
	1–12 months	Artichokes, dry beans, carrots, celeriac, celery, garlic, horseradish, jicama, kohlrabi, leeks, onions, parsley, parsnips, chili peppers, potatoes, pumpkins, rutabagas, salsify, turnips
Grains	6–12 months	Barley, buckwheat, corn, oats, millet, peanuts, rye, soybeans, sorghum, alfalfa, clover, crown vetch, tall fescue, orchard grass, ryegrass, timothy

Adapted from Gast [74] and Part [75]

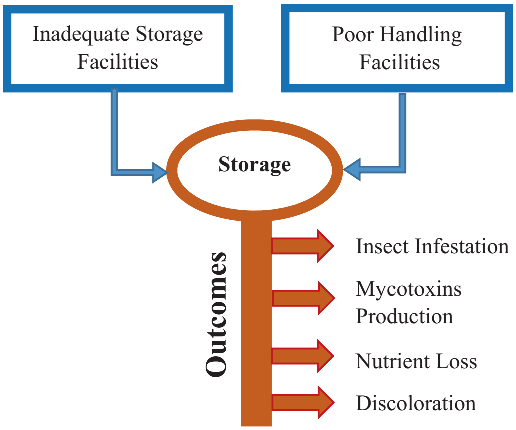

Fig. 6.8 Negative outcomes due to inappropriate storage conditions

plant-based food materials; however, the wastage lessened by the optimal storage conditions [71–73].

To minimize the losses and to increase the shelf life along with the quality, proper storage conditions including temperature, humidity, respiration rate, and light are essential. The microorganism growth rate depends on the characteristics comprising the chemical structure, PH level, and water activity of the food as well as on the temperature, relative humidity, and respiration rate. The appropriate storage time period of some selected fruits, vegetables, and grains is represented in Table 6.2.

If the appropriate conditions are maintained properly, a higher quality of food product may be sustained for a long time; otherwise, a negative outcome may arise which is extensively represented in Fig. 6.8.

11 Chemical Preservation

Over the course of different food preservation processes, many chemicals are used as preservatives. Adding food preservatives in foodstuffs averts wastage by preventing food from microbial spoilage and thereby preventing changes in quality and maintaining freshness. There are extensive categories of food preservatives, but the common food preservatives are ascorbic acid, sodium benzoate, sodium erythorbate, potassium sorbate, calcium propionate, citric acid, sodium nitrite, and calcium sorbate. Improper using of these preservatives may raise some adverse issues relating to the human health.

There are numerous categories of reactions, which may take place as a consequence of food additives. A number of these reactions act as a medium of the allergic cause, while lots of the others do not seem to be allergic, but pretty intolerable. Different types of adverse health effect may be caused as a result of improper use of food additives that are presented in the following Fig. 6.9.

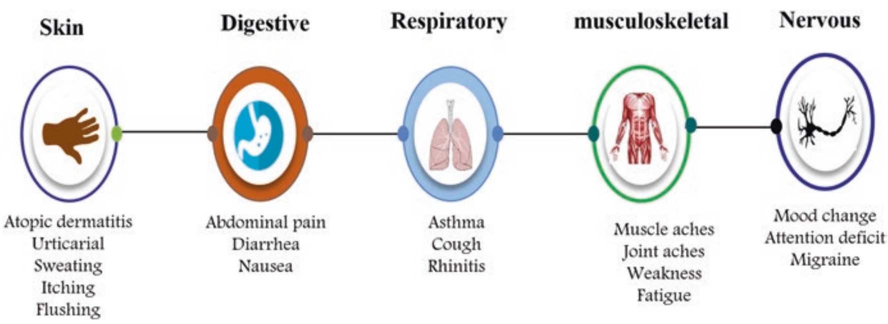

Fig. 6.9 Diseases occurred due to improper use of food additives

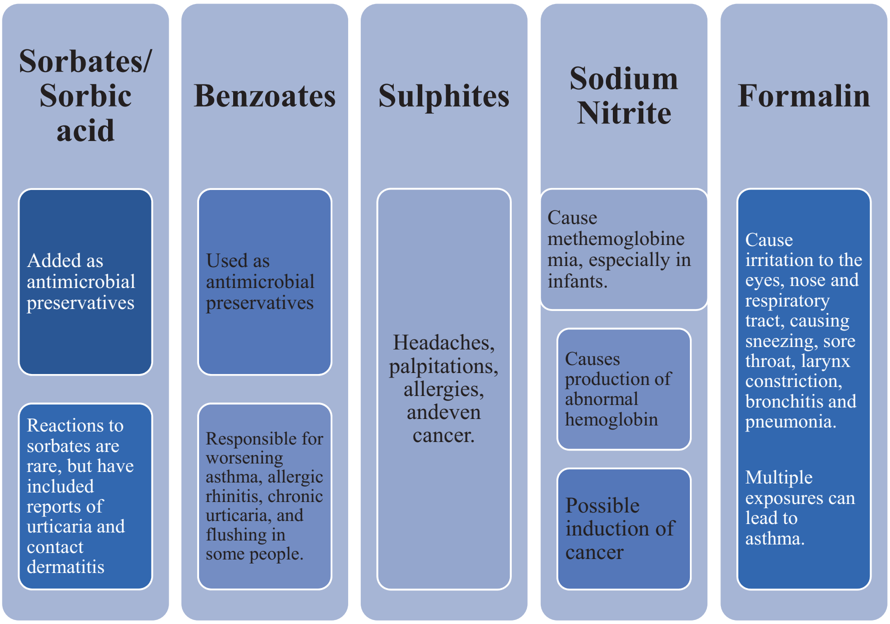

Fig. 6.10 Harmful effects of using chemicals for food preservation [76, 77]

The diverse nature of chemical side effect may take place in adding preservatives. There are some commonly prevailed harmful effects of using chemicals for preservation as represented in Fig. 6.10 [76, 77].

Appropriate amount of chemical preservative is not harmful at all for human. Excess amount may cause severe contamination of food. People in developing countries add too much chemical without knowing the exact amount and consequence of excess chemical. As chemical contamination is a warming contamination, proper regulation and monitoring must be executed in order to avoid this type of food contamination.

12 Packaging

Packaging system may successfully reduce the environmental damage that occurs due to exposure to water, light, gases, odors, and microorganisms. For instance, an optimum barrier packaging can easily reduce the evaporation or oxidation of the flavor or aroma.

Different additives including antioxidants, stabilizers, slipping agents, or plasticizers among others are frequently added to the polymers with the intention of increasing the properties of packaging materials. Any types of interaction between the food and the packaging material may lead to the conveyance of the additives, which is known as migration [78]. This migration can pose a health risk for a human being if any type of toxic substance is present here. Compounds that have a molecular mass lower than 1000 amu may transfer and cross the polymeric or paper layers, typically reach the food, and be dissolved in it. Migration nature basically varies on both the characteristics of food and the exposure conditions.

12.1 Plastics

For the packaging of food, typical polymers are used such as polyethylene (PE), high-density polyethylene (HDPE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), and polycarbonate (PC). Moreover, multilayer materials combining some of them can also be used with the intention of improving the final packaging properties. In addition, numerous ingredients can be added to the polymers with the purpose of improving the polymer features, for instance, UV filters, antioxidants, plasticizers or colorants, adhesive layers, and printing inks or varnishes [79, 80, Margarita 81]. All of such additives can act as potential migrants [81, 82]. Plastic recycled materials have correspondingly superior significance, as they might comprise of different chemical compounds that may migrate to the food samples [83]. A list of polymer packaging materials along with the harmful migrating component to the food is extensively represented in Table 6.3.

12.2 Paper and Board

Paper and board are frequently utilized for packaging dry food, for example, flour or sugar, rice, cereals, or frozen food. In that time, migration from paperboard additives or from printing inks to cuisine may happen. Furthermore, the paper is recycled more than any other packaging material, and the utilization of recycled materials may generate food contamination of ingredients, for instance, mineral oils or plasticizers producing both from printing inks or adhesives [85].

Table 6.3 Migrating components from polymer packaging materials to food [84]

Packaging material	Migrating component	Food	References
PS	Styrene dimmers/ trimmers	Instant food	[85]
PS cups	Styrene	Yogurt	[86]
PS	Styrene	Water, milk, cold and hot beverages, olive oil	[87]
Polyester cookware	Benzene	Olive oils	[88]
PVC films	DEHA	Cheese	[89]
LDPE, HDPE, PP, microwave packaging	Irganox 1010 (I-1010) cPET	Fruit simulant liquids (FSL)	[90]
PVC films	Dioctyl adipate	Cheese sauces	[91]
PVC films	DEHA	Cheese	[92]
Polymeric material	Styrene	Dairy products	[93]
PP cups	DEHA	Dairy products	[94]
Polystyrene	Styrene/ethylbenzene	Dairy products	[95]
PP cups	2-Decanone	Cheese sauce	[96]
PS (+recycled material)	Monostyrene	Dairy products	[97]
PS+ ABS+ waxed paperboard	Mineral hydrocarbons	Dairy products	[98]
Wax coatings	Mineral hydrocarbons	Cheese sausages	[99]
Polymer	Dioctyl phthalate	Milk	[100]
PS	Monostyrene	Milk	[101]
PP	Monomers	Yogurt	[102]
PS	Styrene	Food oil	[103]
PS	Styrene	Cheese, dessert, meat products	[104]
PVC	DEHA	Cheese	[105]
LDPE	Naphthalene	Milk	[106]
ABS	Mineral hydrocarbons	Dairy products	[107]
PC	Bisphenol A (BPA)	FSL	[108]
PVC films	DEHA	Bread, olive oil, cheese, meat	[109]
PVC	DEHA	Microwave fatty foods	[110]

12.3 Metal Contamination

During food preservation by packaging, metal can also act as a great source of contamination that contaminates foods in dissimilar pathways [111, 112].

1. Contamination might happen because of the direct interaction of the apparatus, tanks, tubes, and other parts of the processing equipment, which are prepared from injurious metal at the time of food processing.
2. Contamination all through the preservation specifically during storage steps such as canning and packaging. For example, toxic metal is used in various containers and cans.

Fig. 6.11 Effect of toxic material on the nutritional quality of food [113]

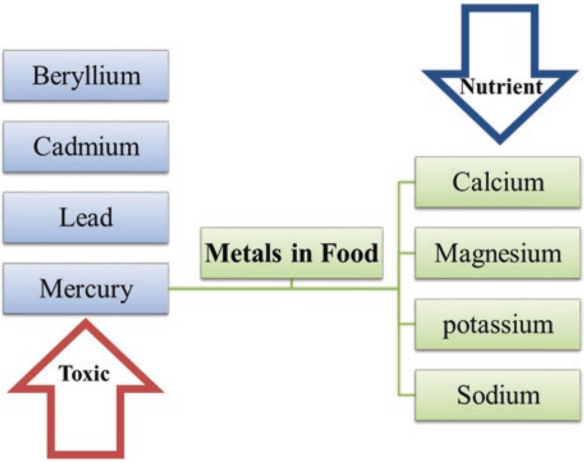

Table 6.4 Migrating components from packaging materials (other than polymer) to food [114]

Packaging material	Migrating component	Food	References
Wooden packaging	1-Propanol	Apples	[115]
Tin	DGEBA	Canned foods	[116]
Metals/plastics/glass/aseptic recycled paper and board cans coated with lacquer	DIPNs epichlorohydrin	Tomato	[116]
Paper cardboard and board	Metals (Zn, Sn, Al, Mn, Ba)	Test foods	[117]
Cartoons (Al-laminated)	Al	Skimmed milk, yogurt drink	[118]
Aseptic	H_2O_2	Milk	[119]
Aluminum foil paper laminates	Phthalate esters (DBP, BBP, DEHP)	Butter, margarine	[120]
Cans	Badge (lacquer)	Water-based simulants	[121]
Aluminum	Al	Food and drinks	[122]
Paper-based food packaging	2378-TCDD/2378-TCDE (polychlorinated dibenzofurans)	Fatty and nonfatty foods	[123]
Ceramic containers	Pb, Cd	Dairy products	[124]
Aluminum	Al	Milk	[122]
Cans	Badge	Canned foods	[125]
Aluminum	Al	Dairy products	[122]
Paper and board	4,4-Bis (dimethylamino) benzophenone (MK), 4,4-bis-(diethylamino benzophenone) (DBAB)	Dairy products	[126]

Figure 6.11 reveals the negative effects of toxic material that may transfer to the food from the packaging materials and their consequences in terms of nutrient reduction [113]. Moreover, a list of packaging materials made of other than polymers, along with the harmful migrating components of the food are extensively represented in Table 6.4.

There are numerous possible ways of contamination of food during processing and preservation. Both intentional and inadvertent actions are responsible in food contamination. Special care needs to be taken into consideration from the preparation to packaging of foods. All sort of possible ways of mixing foreign harmful materials must be avoided over the course of preservation. Proper sanitation practices, discarding harmful preservatives, and controlling required preservation conditions would ensure the safe quality of preserved foods.

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Chapter 7
Challenges and Mistakes in Food Preservation

Abstract Many mistakes are made, and challenges are encountered in food preservation in developing countries. The mistakes affect the effectiveness of food preservation techniques negatively. Food preservation mistakes more frequently take place in developing countries than in developed countries. Most of the mistakes are associated with lack of attention, guideline, as well as knowledge relating to food preservation system. Although numerous mistakes take place during preservation techniques, avoiding the key mistakes would lead to eliminating many other mistakes. Apart from avoidable mistakes, many challenges are encountered on a regular basis in developing countries. Diverse factors contribute to the overall challenges in food preservation systems. Lack of facilities, incorporation of technology, technical support, and necessary knowledge are the key factors that severely reduce the performance system. In this chapter, an extensive review of common mistakes and challenges associated with food preservation in developing countries has been discussed in great detail.

Traditional food preservation techniques offer many advantages, including easy application and maintenance. The techniques constitute knowledge passed on to generation to generation over the unknown long period. In other words, the traditional processes are completely experience based and developed from trial and error basis over several generations. As such preservation techniques are less resource intensive in nature, these sustain from generation to generation. However, there are rooms for improvement in terms of quality of food and the effectiveness of the process.

In this chapter, we will discuss the mistakes that take place during food preservation in developing countries. The avoidable situation that makes unhygienic and ineffective food preservation in developing countries is treated as mistakes in this chapter. There is a diverse nature of mistakes associated with each type of preservation that prevails around the world. However, the core or very common ones have been discussed in this chapter. The mistakes take place not only at the domestic level but also at the industrial level in developing countries. It does not necessarily

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mean that all of the mistakes lead to the same consequence of the food. The effect differs with the degree of mistakes, types of food preservation, as well as the type of food materials. Mistakes in food preservation may cause mild to severe effect on food quality, energy consumption, as well as preservation time.

The effectiveness of process and quality cannot be enhanced due to the many challenges encountered across developing countries. Challenges vary with places, process, and even types of food materials needed to be preserved that impact on food preservation. It is quite impossible to discuss all of the challenges associated with food preservation techniques. Therefore, this chapter is not designed to cover all of the challenges in detail.

In this chapter, the general challenges and mistakes accompanying with almost all of the traditional food preservation techniques are discussed. Following this, very specific discussion on the challenges associated with different methods of food preservation in developing countries has been presented briefly.

1 General Challenges in Traditional Food Preservation in Developing Countries

There are some very common challenges that arise during traditional food preservation techniques in developing countries. However, challenges of a specific nature encountered by the people of a specific region are out of the scope of the current discussion. The general challenges can be subdivided in a diverse way as presented in Fig. 7.1 and discussed in the proceeding sections. To achieve a secured food condition is now becoming an enormous challenge, because of the complex several factors, which magnify it.

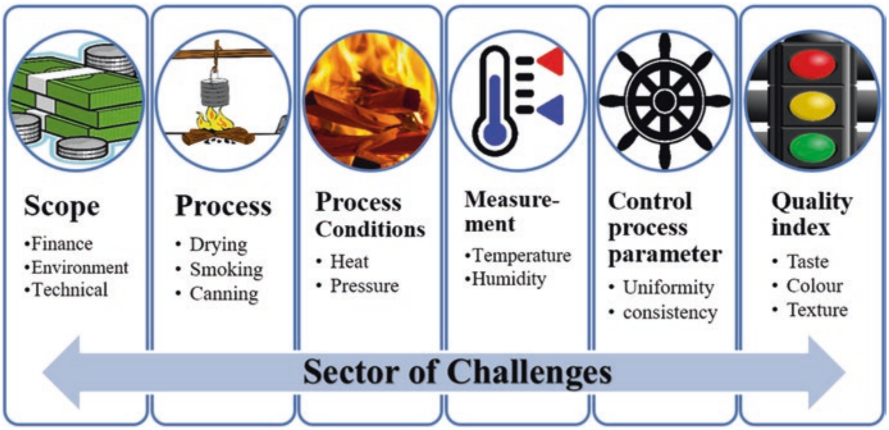


Fig. 7.1 Sector of general challenges in traditional food preservation

1.1 Financial

Most of the food preservative techniques in developing countries are based on traditional approach along with a relatively insignificant amount of modern technology oriented. Poor rural people mainly practice the traditional approaches where they cannot even afford to buy the required staff to accomplish the preservation process successfully. With the progress of technology, there are many user-friendly options that are now available which can be integrated without altering the sociocultural value of traditional foods. Lack of finance is the main hindrance for the village people to cope with the effective options in the traditional food preservation techniques.

1.2 Energy

Energy is indispensable in completing any type of food preservation. High-grade energy such as electricity can facilitate the process in an efficient way. For example, cooling and refrigeration completely depend on the supply of reliable source of electricity or liquid fuel such as diesel. Due to limited financial investment, poor people cannot utilize electrical energy and rather use available low-grade energy. As most of the preservation relies on biomass-based fuels, many technological advancements cannot be availed in absence of electrical energy. Moreover, the traditional energy takes enormous human hours in collecting, drying, and preserving.

Along with having limited access to electricity, the high price of other forms of energy such as oil and gas had a significant effect on food preservation in developing countries.

1.3 Environmental

Many of the food preservation techniques depended on climate conditions. For example, drying of food material mainly depends on the availability of heat coming from the sun. Environmental conditions including temperature and humidity substantially affect the performance of food preservation. Extreme temperature, high humidity, fluctuating temperature, and excess rainfall are a couple of main environmental factors that directly affect the growth and propagation of microorganisms. These uncontrolled environmental conditions significantly hinder the process of food preservation. As rural food preservation system relies on natural resources, the fluctuation of weather causes a significant amount of food waste.

Moreover, the raw food material supply in developing countries varies with seasonal changes. Sometimes extreme weather conditions prevent in ensuring the right amount of raw food material at the time of demand.

In addition to these, freshwater resources are used at different stages of food preservation. This vital freshwater is not readily available in the different regions of developing countries [1, 2]. Water used in food preservation is not hygienic enough and carries various harmful microorganisms. Consequently, a greater risk arises in proper food preservation.

On top of these, unfavorable weather condition not only contributes to food waste but also imposes a constraint on human performance as well as limits working hour [3]. The extreme weather is even out of working condition for vulnerable people of the community. This hinders the right pace of the food preservation process.

1.4 Technological

Most of the food preservation techniques practiced in developing countries are carried out manually and with less modern tools. The tools required to perform the food preservation are locally manufactured. In most of the case, proper apparatus for efficient food preservation is typically lacking. Consequently, people of less developed countries use obsolete tools to accomplish food preservation. These obsolete processing equipment cannot ensure high efficiency in food preservation in terms of time and energy utilization [4]. Consequently, the preservation cost of per unit food materials increased significantly. On the other hand, accommodation of new technology in food preservation is a challenging issue.

1.5 Sociocultural

The sociocultural structure comprises of sets of activities and interactions that people are involved with in their life considering demography, ethnicity, religion, and gender [5]. Food is not merely the necessity of human being, but it also is a key component of culture [6]. Food preservation techniques of different type are encountered sociocultural regulation in various degree. In many cases, these sociocultural regulations resist people based on their gender and ethnicity in involving in food preservation [7].

1.6 Informational

The information gap in food preservation hinders the adaptation of the latest research-based findings to improve the quality of food. Rural people have very limited access to information and communication technology (ICT). In many cases, information regarding appropriate preservation techniques is not shared with the rural people due to the lack of ICT access. Consequently, these people are deprived of attaining advanced cost-effective solution of their food preservation problems that the rapid growth of ICTs offers.

1.7 Educational

As in agriculture, related occupations including farming and preserving are not taken as an attractive occupation in developing countries. Most of the educated people are not interested in involving in agriculture-related occupation. Consequently, people involved in food preservation are not too literate at the root level. Even there is no technically sound supervisor in most of the food preservation centers, as individual-level food preservers account for the lion share in developing countries. Moreover, there are very insignificant educated people who are associated in the administration level in the case of food preservation industries. In addition, the labor force of the food preservation industries is not educated enough. It can be said that most of the mistakes and involuntary loses during food preservation are caused mainly due to lack of proper knowledge of the appropriate techniques.

In many cases, the important piece of knowledge is circulated within the academics and researchers, while the people directly dealing with food preservation are not informed of the latest knowledge of particular techniques. Moreover, the knowledge, in particular, is not easy for the people as it is beyond their grasping capacity.

This lack of proper knowledge not only affects the performance of the preservation but also significantly affects food safety.

1.8 Lack of Skilled Labor

Food preservation in developing countries is manually processed and a labor-intensive process. Skilled labors in food preservation system are of the great challenges. As most of the food preservation system is still accomplished manually, a significant amount of human hours is required. On the other hand, people especially the young generation now prefer mechanized works. Consequently, shortage of skilled and semiskilled manpower results in disruption in food preservation system.

1.9 Process Feasibility

There are various types of food preservation techniques that are available in developing countries. Individual techniques have diverse advantages and disadvantages over other types of preservation techniques. People in developing countries prefer one technique over the other processes on the basis of the experience of the predecessors. Therefore, a particular food preservation technique prevails in a specific part of the globe.

This trend of preference of a particular food continues generation to generation. Sometimes, people are so strict in their practiced techniques; incorporating alternative techniques faces significant challenges. Lack of knowledge in comparative benefits in different food preservations, financial constraint, and risk of failure in the new process are the main reason for avoiding adapting alternative techniques in rural areas.

Many a time, changing approach to preservation technique results in substantial changes in production. As there is no optimization in terms of cost, energy, processing time, and quality, it is pretty much challenging to identify the best specific preservation techniques.

1.10 Application of Right Process Conditions

Different process conditions including temperature, pressure, humidity, and presence of air are involved in food preservation techniques. These process-oriented parameters significantly affect product quality, energy consumption, processing time, as well as cost. Most of the case, people in developing countries do not know the exact process condition. Consequently, the preservation technique provides lower-quality and energy-intensive preserved food.

As process conditions vary with the variation of food materials, a sound knowledge of this diversity must be taken into consideration for efficient preservation. For example, drying of a certain fruit needs a higher temperature than other fruits and vegetables.

Energy consumption and quality of processed food can be manipulated with optimum process conditions. However, most of the people involved in food preservation are not knowledgeable enough to provide the right preservation parameter. The severity of losses of this challenge varies between preservation techniques. In brief, the intensity of the challenge-related process conditions varies with the number of preservation parameters. In other words, a single process parameter oriented technique encounters fewer challenges than its multivariable counterpart.

1.11 Measurement of Process Parameters

Similar to the knowledge of preservation condition, measurement of process condition is also a vital challenge for the people of developing countries. Most of the time, the conditions are left unmeasured due to the unavailability of measuring tools.

In general, people use their experience and guess capacity in order to measure the intensity of the process parameters. Consequently, the real intensity of the process parameters is not measured at all. In some case, people use non-reliable locally made measurement tools that result in an erroneous measurement. The challenge in measurement accounts for the substantial negative impact on the food quality. Moreover, inappropriate measurement of these parameters can cause remarkably excess time, energy, as well as the cost of the preservation of food material.

1.12 Control of Process Parameters

Control of process parameter in different food preservation techniques in developing countries is a great challenge. There are many situations wherein uncontrolled process parameters cause severe loss of food during the preservation. For example, the heat required for drying comes from uncontrolled burned fire and causes an improper increase of temperature of the air that passes to the food. In many cases, there is no regulation system of process parameter over the course of the food preservation technique.

The uncontrolled process parameters result in nonuniform distribution of the quality parameter. Consequently, the shelf life of the preserved food decreased remarkably. For example, the uncontrolled flame in the smoking process causes nonuniform distribution of heat and smoke; eventually, the taste and quality cannot be attained as uniform as expected.

Therefore, controlling preservation parameters including pressure, temperature, and air velocity involved in different food preservation techniques is a great challenge in achieving energy-efficient food preservation system.

1.13 Setting Appropriate Quality Index

The best quality of food materials refers to the preserved food that encompasses properties as close as the fresh one. Preservation conditions and time significantly affect the quality of food materials of all kinds to a different extent. Quality measurement is a challenging task for the scientist and technologist, let alone the people involved in food preservation in developing countries. Setting quality standard and measurement of quality both are important to maintain a high quality of finished foods.

First of all, no targeted standard of the quality index is followed during food preservation. People leave the food in the preservation system for an arbitrary time without considering the quality attributes of foods. As there is no set quality index maintained, the duration of preservation techniques is completely based on speculation and experience.

On the other hand, the quality measurement technique, based mainly on visual inspection, is not reliable enough. In most of the cases, there is no facility of quality measurement of food material. Eventually, many food materials are wasted due to the challenges in quality measurement.

1.14 Lack of Technical Support and Counselling

Many a time, rural people encounter technical problems in connection with food preservation systems. Moreover, they do not know the right approach and tricks to accomplish in many cases due to lack of expert guidance. An appropriate piece of advice may save a substantial amount of foods from waste. In these cases, they rely on the experience of the local people. People who are facing any technical problem do not have any access in counselling service in most of the developing countries. Specialized knowledge, sometimes, critical for overcoming the challenges come across by rural people.

2 Specific Challenges and Mistakes in Food Preservation Techniques

The specific challenges are distinct and diverse in nature. Challenges and mistakes vary between traditional food preservation processes. Although it is not possible to gather all of the challenges and mistakes associated with individual food preservation, frequently encountered challenges of different food preservation techniques have been discussed in the following section.

2.1 Refrigeration and Freezing

2.1.1 Putting Wet Vegetables in the Refrigerator

In many places, fruits and vegetables are directly left in refrigeration straight after washing. The extra water present in fresh food may cause a remarkable proliferation of microorganism. It is better to dry the food properly prior to putting into the refrigerator.

2.1.2 Putting Too Much in the Refrigerator

Cold air needs to take away the heat from stored food to reduce the temperature of food. As convection heat transfer takes place inside the refrigerator, sufficient amount of cold airflow is essential to maintain the food in the required cold level. In many cases, people put so much food in the refrigerator that can reach at an expected cold level within a reasonable time. As it is taught that the volume of the refrigerator is the capacity of the refrigerator, people put as much food as it can be adapted inside the refrigerator. This common refrigeration mistake causes a remarkable amount of food waste.

2.1.3 Wrong Container

A container is used for preventing food from freezer burn as well as picking smell from other foods. Most of the cases, very little attention is paid in the nature of container. A container that is flexible and rigid should be airtight. Resealable bags and airtight plastic box can be used in overcoming these mistakes.

2.1.4 Mixing Foods of Different Kinds

People make these mistakes across the globe. Mixing different foods together is not a good decision as it causes interchanges of flavor, microorganisms, and emitted gases. Some of the fruits and vegetables emit gas such as ethylene that causes faster ripening. In addition, infection from one food to another is easy once different foods are mixed together in the refrigerator without a separator. The cross-contamination can take place even in the refrigerator, while the foods are not kept properly and separated from one another.

2.1.5 Larger and Uneven Foods

Keeping larger foods in the freezer and refrigerator takes longer time in reaching heat toward the core of the food. This often causes deterioration of foods from the interior portion. Especially for the freeze-drying, the food sample must be smaller enough to transfer heat quickly throughout the sample. The food even would not rehydrate properly due to large size.

In addition to this, mixing of different size and shapes causes uneven cooling effects. Eventually, proper refrigeration is hinders due to the mixture of foods with different size and shapes.

2.1.6 Whole Fruit with Tough Skins

These mistakes mainly occur during freeze-drying. Peels are created in such a way that they hinder moisture transfer adjacent to the peel. The peel also acts as a bio-burden of the fruits. In order to increase the moisture transfer rate during freezing, the skin must be peeled properly. In many cases, skins of bigger fruits such as mango are peeled prior to keeping in the freezer; however, the smaller foods as grape and tomatoes are put unpeeled. This mistake causes more energy and time to complete the freezing.

2.1.7 Hot Foods

Hot food, especially leftover food, is directly kept in the refrigerator for future use. This great mistake affects the food quality aspects as well as energy consumption. The hot food causes the increase in the temperature of the neighboring foods that result in a proliferation of microorganisms. Moreover, the refrigeration consumes extra energy to cool the hot food at room temperature. Therefore, it is better to leave the food outside until it reaches the room temperature. This approach saves both the quality of food and energy consumption.

2.1.8 Improper Temperature

Optimum refrigerating temperature is vital to keep the food fresh by retarding microbial growth and chilling effect. In many cases, the less trained person in developing countries does not maintain this critical parameter. This happened in most of the household refrigeration as well as industry level.

2.1.9 Cooling Rate

The cooling rate is vital in the quality of chilled food materials. The optimum cooling rate is needed to be maintained in order to attain better quality food [8]. Excess cooling rate results in texture-damaging phenomena, woolly texture, and cold shortening of plant-based food and animal-based food, respectively. While slow cooling is not expected for the freezing of food, materials as it causes larger ice crystal. Slow freezing causes more damages to the tissues due to large ice crystal development than fast freezing [9]. Therefore, maintaining an optimum cooling rate is a challenge for people with no expertise in the field of refrigeration and freezing.

2.1.10 Safe Temperature Maintenance

Like cooling rate, chilling temperature maintenance is important for avoiding the chilling effect. There is a certain temperature below which foods specially are damaged and causes quality deterioration including off-color, unexpected flavor, external and internal damage, and low water holding capacity. The wide range (0–20 °C) of the critical temperature, as shown in Table 7.1, makes it challenging for the people of developing countries. A slight variation of chilling or freezing temperature may cause a substantial amount of food damage.

Controlling appropriate temperature and cooling rate is the main challenge in low-temperature food preservation techniques in developing countries. Moreover, uniform distribution of temperature is vital to be maintained throughout the storage system.

Table 7.1 Chilling effect of selected fruits and vegetables [10]

Class	Produce	T_{inj}(°C)	Chilling injury symptoms
A (0–5 °C)	Apple	2–3	Internal browning, soggy tissue
	Guava	4.5	Pulp injury, decay
	Watermelon	4.5	Pitting, objectionable flavor
	Orange	3	Pitting and brown stain
	Potato	3	Sweetening
B (6–10 °C)	Cucumber	7	Pitting, water-soaked spot
	Eggplant	7	Surface scald, blackening of seeds
	Okra	7	Discoloration, pitting
	Papaya	7	Failure to ripe, off-flavor
	Pumpkin	10	Decay
	Grape	10	Scald, watery breakdown
C (11–20 °C)	Banana	11.5–13	Dull color
	Sweet potato	13	Decay, pitting, internal discoloration
	Tomato	13	Poor color when ripe
	Mango	10–13	Discoloration of skin, uneven ripening

2.2 Storage

2.2.1 Improper Storage Temperature

Storage temperature is a vital parameter for fresh or processed food preservation in any form of storage place. Storage temperature varies with products. Although it is very hard to maintain an exact storage temperature with the available facilities in developing countries, a zone or range of temperature can be easily maintained. Most of the cases, an improper temperature in the storage system causes a significant amount of food waste during storage.

Fluctuation of temperature is also vital for food storage. In most of the cases, there is no monitoring system of temperature fluctuation in food storage of developing countries.

2.2.2 Light

Most of the cases, people are heedless about the effect of light on storage foods. The impact of light mainly depends on the energy carried by light and on the composition of food. Therefore, the sensitivity of light of any types varies from foodstuff to another. For example, milk and dairy products are highly susceptible to photodegradation due to the component riboflavin. There are different photosensitizers that prevail in different foods such as antioxidants, fat composition, sulfur compounds, as well as heavy metals [11–15]. Light with a low wavelength ranging 420–520 nm affects negatively on the foodstuff during storage.

In many cases, food storage design allows direct sunlight irradiation to stored food and causes substantial degradation of food quality.

2.2.3 Mixture

Storing different foods at the same conditions is not scientifically appropriate for a set of reasons. Firstly, storing conditions vary with the kind of foods. Therefore, storing different foods at same storage conditions is a great mistake. In developing countries, wide varieties of fruits and vegetables are kept in the same storage conditions without considering their appropriate storage conditions. Secondly, the emission of ethylene varies with the types of fruits and vegetables. Some fruits such as apple give off ethylene at a higher rate and cause faster unexpected ripening of other neighboring foods. This gas even drives to rot at a faster rate than other fruits and vegetables.

Finally, this mistake even causes a mixture of odors of different fruits and vegetables and changes the identical taste of different foods. For example, a strong odor of onion can easily transfer to the neighboring vegetables such as potato. Avoidance of this type of mistakes needs proper knowledge of proper storage conditions and their comparative studies.

2.2.4 Wrong Location

Selection of a proper storage place is as vital as maintaining proper storage. An inappropriate storing place with a leaky basement, damp locations, and a low land that is susceptible to water retention during rain are some of the instances. Farmers of developing countries do not pay attention in the place of storage system and rather consider the viability in other factors.

Food storage must be placed in a cool, dry, and out-of-direct sunlight place. In addition, the temperature of the place should not fluctuate significantly. Sometimes, this high fluctuation of temperature causes loss of foods.

2.2.5 Unorganized Food Storage

Unorganized storage food leads to damage in two ways: excess weight and keeping the older foods at the bottom or back of the storage system. When foods like potato are stored in bags and kept one after another without considering the heavyweight exerted on the bottom bags, damage can easily occur. In this case, farmers should be careful about the loading capacity of the individual types of foods.

Secondly, fresher foods are dispatched first than the earlier one. This mistake sometimes causes loss of a remarkable amount of foods. Two main reasons can be attributed to this mistake: no leveling system and difficulties in unloading the food from the bottom or back of the storage system. In avoidance of this mistake, the food should be organized in such a way that the oldest food can be accessed easily.

2.2.6 Moisture Content

Moisture content, and especially dry grain storage, is a vital factor in the proliferation of the microorganism. Most of the time farmers do not have access to an analytical moisture measurement system. Instead of measurement meters, some forms of indicative techniques such as biting using teeth, pinching, or even keeping the grain in salt are practiced to observe the safe moisture content. However, these indicative procedures result erroneously in most of the cases. The mistakes in safe moisture content in dried food cause faster proliferation of mold and microorganisms.

Moisture measurement tools are not available in most of the storage facility in developing countries. Consequently, rural people are bound to measure the moisture content of the food through indicative observation. Moreover, uniform distribution of moisture, heat, and air is the main challenging task in food storage system.

2.2.7 Insect Pest

Insect control is a great challenge for the rural food storage system. An enormous amount of fresh and preserved food is wasted due to the insect. Due to the low quality of the infrastructure, the control of the insect is quite difficult in developing countries. In addition to this, the high cost of synthetic pesticides is a deterrent in the application of those in stored food in rural areas.

Selection of place and the storage condition are vital factors in the storage of both fresh and processed foods. However, the conditions are beyond the control of rural people in most of the cases.

2.3 Blanching

Although blanching is a pretreatment of other food preservations, it is very common in developing countries. In general, three mistakes regularly occur over the course of blanching in developing countries. The mistakes are as follows:

2.3.1 Incomplete Heating

During blanching, water must be reached to its boiling point. In many cases, people do not allow the water to come to the boiling point. Prior to boiling, the vegetables are taken away from the hot water. This mistake causes an incomplete shocking effect during blanching.

2.3.2 Not Shocking Properly

Immediate cooling ensures proper shocking and further cooking after boiling. If the boiled vegetables are kept out from iced-cold water, the vegetables will lose its freshness and become messy. In villages, people get inadequate access of ice-cold water, and the vegetables are kept outside of hot water for hours. These mistakes result in an incomplete shocking effect that is required for proper blanching phenomena. Consequently, the crispiness and the fresh, vibrant color are not present in these blanched foods.

2.3.3 Proper Ratio of Salt

Salt is a key component for the blanching process to keep the flavor locked in the vegetables. The water-salt solution prevents natural component specially sugar and salt from migrating from food. People of developing countries put salt without knowing the appropriate ratio required for blanching of particular food materials.

Although blanching is an eraser treatment, there are still challenges that arise during the process. The knowledge of proper level of heating and cooling is vital for the quality of food. People in rural areas apply a common rate of heating and cooling for varieties of foods. Consequently, most of the foods are not properly blanched due to their diverse nature.

2.4 Drying

Drying in improper conditions even causes the growth of microorganism in tremendous ways. As higher temperature zones are favorable for some microorganisms, uneven drying may cause the growth of microorganism. This scenario may be observed as a consequence of several mistakes that take place during drying.

2.4.1 Large and Uneven Samples

The sample size is an important parameter in energy and time consumption in the drying of food materials. In conventional drying system such as solar drying, hot air drying, and similar to these, food samples start drying from the outer surface to the core. Many people do not pay any attention in relation to the size and shape of the sample at all.

A large sample takes considerably longer time to dry. In addition to this, the core of the sample even becomes incompletely dried when people think the sample becomes dried after observing the outer surface. In these circumstances, the microorganism starts growing from the core of the sample. The consequence of this mistake is severe in spoiling food materials during preservation.

Moreover, samples with different sizes are kept in the dryer to remove moisture. This is another mistake causing waste of food material remarkably. In this case, uneven dehydration of different samples occurred as the drying rate depends on the size of the sample. Similarly, combination of different foods may also cause food waste even after drying. As different foods dry at a different drying rate, the combination is not a good idea.

2.4.2 Improper Drying Conditions

As drying involves simultaneous heat and mass transfer, factors affecting these transport phenomena must be controlled. Temperature, humidity, and airflow are some of these parameters. In natural conditioned drying such solar and sun drying, no care has been taken into action in most of the cases. Even the mistakes happen on a regular basis in the controllable drying system. In hot air drying with different sources of energy, the temperature of the air and its distribution are not monitored properly. In most occasions, arbitrary airflow is provided to the foods resulting in improper drying.

2.4.3 Nonuniform Airflow

This mistake mainly happens especially in hot air drying of grain and grain-like food materials. When grain depth and compactness are not uniform, the distribution of hot air is not the same throughout the system. This is because air flows through the route of shortest resistance.

2.4.4 Over-Drying or Incomplete Drying

Due to the lack of quality measurement facilities and knowledge, rural people often dry food inappropriately. In most of the cases, uneven and incomplete drying is observed in different traditional dried food techniques. On the other hand, over-drying is also an abundant phenomenon, which results in additional energy consumption and quality deterioration. In addition, over-drying below the safe-storage moisture content results in a loss of value of the foods especially crops.

2.4.5 Slow Drying Rate

In order to dry foods, rural people take advantages from solar heat. In this drying process, the drying temperature is not sufficient to drive rapidly the moisture from the food materials. Generally, the temperature is close to air temperature ranging 28–35 ° C that is the operating temperature in sun drying. For example, the average temperature level in the northern part of South Africa is 28 °C [15, 16]. This low heat energy causes slow drying and takes a significant amount of time to attain expected dried foods.

2.4.6 Uncontrolled Drying Conditions

Drying conditions, especially temperature in hot air drying, are not maintained at the required level. During the drying, people just confirm whether the air is hot or not. The temperature of the air is not properly maintained in most of the developing counties in the farming level. The negative effect of this mistake is so serious that it causes an enormous amount of food waste.

Most of the cases, controlling and measurement of drying conditions are the major challenges for the farmers. Uncontrolled drying conditions severely damage food and consume excess energy to complete the drying process.

2.5 *Packing*

Proper packaging is vital for ensuring the better quality of food materials. In absence of appropriate packaging, it is almost impossible to retain the benefits of other preservation or processing strategy. A huge difference would be made between a sample with and without proper packaging.

2.5.1 Moisture in Package

People are sometimes careless about the moisture in the package. Both sealed water during packing and leaked water during storage must be taken into account Sealed moisture is fixed since the assembly time, and the moisture may reside in the ambient atmosphere, be adsorbed to free surfaces, or be dissolved in component materials. Even for hermetically sealed containers, there is a chance of present of sealed moisture. On the other hand, leakaged moisture is caused due to the permeation into the package from the external environment. The of leaked water increases with storage time and depends on the details of the seal design as well as the storage conditions.

2.5.2 Inappropriate Packaging

The primary purpose of packaging is to develop a hindrance for microorganisms and resistance to heat and mass (moisture and other chemical) transport. Packaging criteria are divergent and distinct for different types of food and the intended duration of storage. Therefore, considering both types of product and the duration of storage must be taken into account prior to selecting the packaging option. Airtight packaging or container is appropriate for long-term storage.

In developing countries, people mistakenly use sack or other permeable packaging to store food for a long duration. These types of packaging cannot ensure the higher shelf life of food.

2.5.3 Wrong Ink

Apart from the performance of the packaging in hindering the growth of microorganism and transport of moisture and other gases, the diffusion of materials sometimes inserts toxic components in the food. For example, harmful ink is used in packaging, especially in plastic bags. In these cases, the ink has potential in food contamination and even change of odor. In addition to this, an enormous number of other chemicals present in packaging materials can contaminate food [17].

Moreover, dirty and unhealthy packaging is regularly used in different places of the developing countries. Minimal importance is given on packaging materials when it comes in food storage and safety in rural areas. In addition to this, making air tight of the package is one of the major challenges that people of developing countries face on the regular basis.

2.6 Smoking

2.6.1 Uncontrolled Fire and Smoke

Soft and smoky meat and fish are highly expected after the smoking process. People are very heedless in controlling fire and smoke. Overheating and nonuniform temperature result in uncontrolled fire and smoke. Overheating causes less smoky and dry finished food. This may be due to the fact that moist surface attracts more flavonoids from smoke than dry foods. Whereas, low heating for a long period provides soft texture juicy smoked food. Furthermore, the uneven distribution may cause hot and cold spot, which result in overheating and incomplete heating. Consequently, under-smoking and over-smoking may take place in the same piece of foodstuff. Both of the scenarios deteriorate the nutritional quality and smoky flavor of finished food.

The process requires constant attention and equipment that can be costly. It is difficult to keep the food moist due to low moisture contents in the smoker, and it is difficult not to contaminate the meat flavor. Problems can occur if the fire is too hot (cooking the meat before it is properly smoked) or if there is not enough smoke or heat (the meat goes bad before it can be smoked).

2.6.2 Wrong Starter Oil

Most of the wood chips do not start producing smoke at first instance. In order to initiate the burning of wood, different types of starter oil is used. Although vegetable oil can be a healty option of starter, people use kerosene as a starter oil in many places for faster process. The consequence of this mistake is terrible since it adds odd flavors in meat or fish.

2.6.3 Dirty Oven or Grill

Many a time, smoking of food is accomplished using dirty grills which produces unhygienic and unhealthy smoked foods. In rural areas in the developing countries, people often neglect the cleanliness of the oven and grill. Consequently, the smoked food is susceptible to the proliferation of microorganisms in many cases.

2.6.4 Wrong Smoke-Producing Medium

Generally, wood is used in producing smoke. Quality of smoke varies remarkably with the types of wood and conditions of wood. The types of wood chips used for smoke production significantly affect the flavor of smoked food. Unseasoned fresh wood needs to be dried prior to using for the production of smoke. Otherwise, it produces irregular smokes along with a stream. Even it ends up smoking food without the desired flavor. In addition, hardwood produces good-quality smoke than softwoods. Using softwoods produces more unpleasant flavored smoke as it contains more air and sap.

Apart from the wrong selection of woods, in many a time, other materials apart from woods are used in producing smoke. For example, scrape tires are used instead of wood chips in many places in Africa which is not a healthy option for smoking consumable foods including fish and meat.

2.6.5 Oversized Fires

Quality of smoke is important in preserving the flavor and the quality of the smoked food. The size of wood used for smoke development is responsible for the quality of smoke. Small-size wood makes cleaner, white, thin smoke and consistent smoking temperature. Whereas, oversized wood produces black, unburned thick smoke and inconsistent smoking temperature. The incomplete burned smoke consists of some volatile components, which are not good for health anyways.

The major difficulties during smoking of foods are controlling heat and handling the food properly [18]. Uncontrolled heating produces uneven quality of smoked food as well as causes wastage of energy [19, 20]. Moreover, the hazardous effect of smoke causes a major health problem in rural areas [21].

2.7 *Pickling*

2.7.1 Preprocessing

Many times, the pickling process requires some sort of preprocess such as boiling. Not all the vegetables require boiling or the same cooking time. For example, cucumber does not require any types of cooking in most of the cases, whereas carrot needs boiling process prior to pickling. People in the developing countries boil different fruits and vegetables in the same way, which causes a significant amount of quality degradation. These mistakes result in an unexpected texture and flavor of the final pickle.

2.7.2 Uncontrolled Salt Percentage

Salt is one of the major ingredients of pickling of food fruits and vegetables. The percentage of salt is vital in the taste of pickled foods. Most of the time, rural people are very careless about the amount of salt in pickled foods. Sometimes, the amount of salt is so high that the pickle is not suitable for consumption.

2.8 *Salting*

The main mistakes in connection with salting are mainly related to the amount of salt and method of implementing salt on the food. The following salt-related mistakes regularly take place during the salting process:

(a) Inadequate salting: The amount of salting governs the process of water migration from the inner part of the food materials. There is a certain amount of salt required below which the salting would be incomplete for a specific amount of food of particular type of food. Many a time, people do know the exact amount of salt that is required for proper salting. Experience passed on to generation to generation is the basis of determining the amount of salt in food material in rural salting process. Even, in most of the cases, the same amount of salt is applied in the different types of food materials. This causes inadequate or overapplication of salt in food. Consequently, inadequate salting takes place, and the shelf life is not increased to the expected extent. Sometimes, a huge amount of food is wasted due to incomplete salting.

(b) Oversalting: In the similar mistake of inadequate salting, in many cases, oversalting takes place. In addition to excess salt, the taste of salted food deteriorates to such an extent that it is not even suitable for consumption.

(c) Impurities in salting: Clean salt must be applied on the food materials. Any form of impurities present in salt definitely mixes with the food. Sometimes, the unhygienic nature of impurities causes enormous discard of salted foods.

Knowledge of the proper amount of salt for particular food materials is a secret for rural people. Inadequate amount of salt cannot offer an assurance of hindrance of microorganism properly.

2.9 Fermentation

Performance of fermentation depends on several factors including the presence of oxygen, temperature, and types of mineral present in water. Selection of the appropriate container for the fermentation process is also a challenging task.

2.9.1 Not Properly Closing the Container

Oxygen is vital for microorganism growth and propagation. Proper closure of the fermented food container can ensure the anaerobic condition. Many of the cases, fermentation producers in developing countries do not take care of this issue. Once the food is exposed in air, microorganism including yeast and mold can easily proliferate in the fermented foods. However, a hermetically closed container is also not a very good idea, as this does not permit to migrate carbon dioxide produced by bacteria properly. Therefore, a cover that ensures direct exposer of atmospheric oxygen is sufficient for the fermentation process.

2.9.2 Unwanted Mineral in Water

Different types of minerals are presented in various proportion of water. However, the mineral content differs with the variation of sources of water. Therefore, the source of water is vital in the fermentation process. Some of the minerals such as chlorine are not favorable for fermentation of food. As chlorine kills bacteria, it is not conducive for bacteria culture that is essential for proper fermentation. In addition, water having no mineral and insignificant oxygen is also not good for the fermentation process. An adequate level of oxygen content is vital for the growth of essential bacteria and yeast during fermentation. People of many parts of the globe are careless regarding the quality of water that is used in the fermentation process. Consequently, the fermentation is not properly accomplished.

2.9.3 Metal Container

Many times, people use metallic containers for fermented food. This is an unfavorable mistake that takes place in developing countries. During fermentation, the P_H level of water decreases significantly and becomes more acidic. The higher acidity causes corrosion of metallic vessels of fermented foods. Consequently, the taste and color of the fermented food may change remarkably.

2.9.4 Too Much Sugar

Sugar is an important ingredient for fermenting many fruits and vegetables. The amount of sugar varies with the species of fruits. For example, some fruits such as grape do not require sugar at all. Too much sugar inhibits the growth of beneficial bacteria that are required to facilitate fermentation. Many a time, people mistakenly put too much sugar in the fermentation solution, and the process cannot proceed at an expected rate.

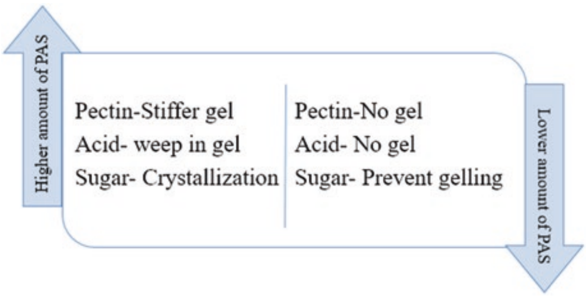
2.9.5 Wrong Temperature

Proper temperature is an essential requirement for the growth of wanted microorganisms for fermentation. Different temperature ranges are conducive for diverse types of microorganisms. Too warm or cold places are not favorable for the fermentation process. In addition to this, temperature fluctuation does not positively affect the process. All of these issues related to temperature cause the growth of unwanted microorganisms. People in developing countries make these mistakes frequently due to being unaware of the proper temperature of a specific temperature of the fermentation process. Consequently, the quality, specially, the expected taste cannot be attained after the fermentation.

2.10 Jam and Jelly

Formation of gel during jam and jelly preparation of fruits mainly depends on three basic ingredients, namely, pectin, acid, and sugar (PAS) as Fig. 7.2 demonstrates. In developing countries, people make many mistakes in connection with the mixing of these ingredients.

Fig. 7.2 Effect of PAS on the formation of gel



2.10.1 Fully Ripened Fruits

Pectin contents vary significantly with the degree of ripeness of the fruits. Unripe fruit contains more pectin than the ripe one. Therefore, a proper mixture of fully ripe and under-ripe provides an appropriate level of pectin to form the gel. Many a time, only ripened fruits are used in jam preparation. Consequently, expected gel formation does not take place. In this way, many unsuccessful jamming attempts cause enormous food waste.

2.10.2 Amount of Commercial Pectin

All of the fruits do not contain the same amount of pectin. For this reason, people need to add extra commercial pectin in jam. However, most of the time the exact amount of pectin required for proper gel formation is not provided. The same amount of pectin is added for varieties of food jam, which results in less or more pectin addition.

2.10.3 Inadequate Amount of Acid

Similar to pectin content, different fruits do not comprise the same amount of acid. As acid is required for gel formation, an adequate amount of acid must be present in jam. In case of fruits with lower acid content, extra acid must be added. In many cases, people do not care about the contribution of acid in gel formation. For this reason, gel formation hinders as a lack of acid content.

2.10.4 Extra Sugar

Sugar plays multiple roles such as privative, flavor enhancer, as well promoter of gel formation. For the purpose of sweetening, too much sugar is added to jam in developing countries. The extra sugar alters the gel structure and starts producing a crystal-like structure in jam. This deteriorates the overall gelling quality of jam and jelly.

Proper knowledge of food content is vital for mixing of sugar and acid during the jamming process. Failure in adding appropriate ingredients produces a lower quality of jam and jelly.

2.11 Canning

Canning is one of the difficult preservation processes as it involves the application of proper temperature and pressure as well as removal of excess oxygen. However, people in developing countries face problems in maintaining proper temperature and oxygen content.

2.11.1 Improper Sealing

Canning needs proper attention when it comes to the sealing issue. Improper sealing may cause dangerous consequences as serious as *Clostridium botulinum* contamination. The mistake mainly happens due to the careless about sealing procedure. In addition, overfilling hinders proper sealing of the foods. For proper vacuum seal, a specific amount of headspace should be kept free. However, too much headspace is not beneficial for venting air from the jar. All of these air content-related mistakes cost significant amount of canning food waste.

2.11.2 Uncontrolled Heating Rate

As canning is associated with heating of the sealed food materials, a slight change in temperature may cause severe spoilage and quality deterioration. In addition, uncontrolled heating or cooling can cause remarkable damage in can or jar. People in developing countries provide uncontrolled heat in the canned food.

In a nutshell, the abovementioned challenges and mistakes are very common in developing countries. There are many other challenges arising in different food preservation techniques, which are not mentioned in this chapter due to the diverse nature of the said challenges that vary from place to place. Moreover, many other mistakes that take place in connection with traditional food preservation technique are not mentioned in this book. The mentioned mistakes are of such a nature that avoiding those would lead to prevention of other potential mistakes associated with food preservation.

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Chapter 8
Possible Solution of Food Preservation Techniques

Abstract Food preservation techniques encountered several challenges regularly in developing countries. Proper interventions must be taken into account in order to overcome the challenges and mistakes that take place during food preservation techniques. No single solution can eliminate the complexities of the challenges due to the diverse nature of the individual solutions. From the basic understanding of the science behind preservation techniques to research on complexity in food preservation, multiple initiatives need to be facilitated on an urgent basis. Therefore, a set of initiatives from all stakeholder is required to overcome food preservation-related challenges. A wide range of solution techniques in order to solve food preservation-related mistakes and challenges has been described in this chapter.

The challenges in food preservation are diverse in nature. There is no single or shortcut solution to overcome these challenges. In addition, most of the challenges cannot be completely tackled without the participation of all stakeholder associated with food preservation. Multidimensional solutions are required in order to solve the challenges related to food preservation in developing countries [1]. Some general initiative in relation to facilities, motivation, and regulation must be incorporated in the food preservation sectors. People of all walks of life from government to farmer along with consumer, educator, and researcher need to make an effort together to solve the food preservation problems. A snapshot of the solution strategies for food preservation-related problems is represented in Fig. 8.1.

1 Sanitation Guideline

Formal sanitation guideline and training facilities are not available in developing countries. There are different sources from where contamination can spread to food during its preservation as Fig. 8.2 demonstrates.

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Fig. 8.1 Solution strategies of food preservation-related problems

Fig. 8.2 Sources of spreading microorganisms during preservation techniques

People who are involved in food preservation are the primary source of bacteria and other microorganisms during preservation of food. Washing hand properly prior to handling food would be one of the mandatory hygienic guidelines for the people. Spitting, smoking, and sneezing should not be allowed in the food preservation zone.

Cleaning of the contact surfaces including transportation, preservation equipment, and utensils is an essential priority in the food preservation system. Many a time, insects like cockroach flies contaminate the contact surface during their food collection [2, 3]. Moreover, in different parts of where food can be stuck develop a conducive environment for microorganism propagation. Separation of waste food materials is also important as microorganism can spread to fresh food from the affected ones [4].

Similarly, one should ensure the purity of water and air used in the different stage of preservation. Many of the microorganisms spread through water and air to the food materials. Moreover, the packaging materials need to be cleaned prior to storing food in it. In brief, all personnel involved in food preservation chain need to receive primary training regarding hygiene.

2 Putting Science Back in Food Preservation

Food preservation is not only related to kitchen and fork but also oriented highly toward scientific concepts. The underlying physics associated with different food preservation is almost understood. Developing preservation system on the basis of the science will enhance the system efficiency significantly along with taking lower time. Many food preservation systems in developing countries do not take into consideration the science behind the process and make many mistakes. Several scientific phenomena take place during each of the preservation technique. However, one or two of the physics dominate individual preservation techniques as demonstrated in Fig. 8.3.

Most of the food preservation practices which take place in developing countries are done without detailed knowledge of related physics. Consequently, severe errors have been observed in the processing system in association with energy consumption and quality of preserved foods. In the following discussion, a simplified and brief consideration of the underlying physics taking place during different food preservation technique is presented.

2.1 Heat Transfer

In many food preservation techniques, heat transfer phenomena take place. The application of heat either prevents the growth or kills microorganisms. In some preservation process such as drying, heat causes migration of water to prevent the proliferation of microbes. On the other hand, heat treatment kills microorganisms through the process like canning and smoking. Both high and low thermal processing involves the different mode of heat transfer to maintain the required temperature

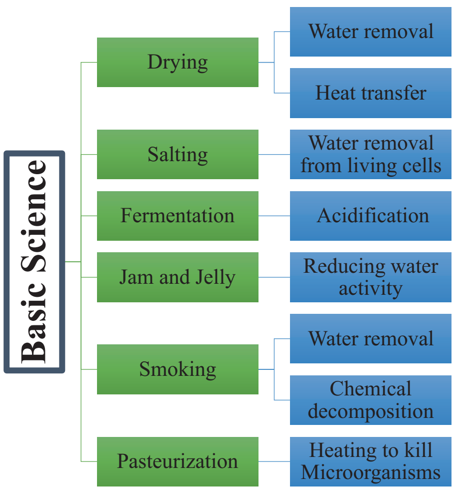

Fig. 8.3 Basic physical phenomena involved in some typical food preservation systems

distribution. Proper consideration of these thermal processing parameters is important in both energy consumption and quality perspectives.

Heat can be transferred from heating source to food materials by three distinct modes of heat transfer, namely, conduction, convection, and radiation. All of the three modes of heat transfer are important for different preservation systems. In brief, conduction dominates transportation of heat within food sample (as shown in Fig. 8.4), whereas convection transports heat from outside to the food sample. On the other hand, heat transfers from the source to food materials without any media in radiation heat transfer.

2.1.1 Heat Transfer Rate

Heat transfer rate needs to be maintained at the appropriate value to attain better quality food. Slight change of heat transfer rate may cause substantial damage to food materials during the preservation process. Therefore, the heating rate must be controlled by incorporating control devices in the food preservation system in developing countries. Uncontrolled heating in thermal processing can deteriorate the food quality especially in drying- and smoking-derived foods [5, 6].

Similarly, the cooling rate needs to be maintained at its optimum level. Both excess cooling and slow cooling can cause unexpected textural damage to food materials during freezing [7]. The cooling rate actually governs the number of ice crystals as well as their size which is represented in Table 8.1.

Selection of proper convective media of heat transfer needs special attention. Heat transfer coefficient varies significantly with the types of convective fluid. Considering this fact, diverse heat transfer fluid including air, water, and oil is used in different preservation processes depending on the demand of the heating rate. Moreover, the phase of fluid is also an important factor in heat transfer rate. For instance, condensation of steam offers a higher heat transfer coefficient than liquid water.

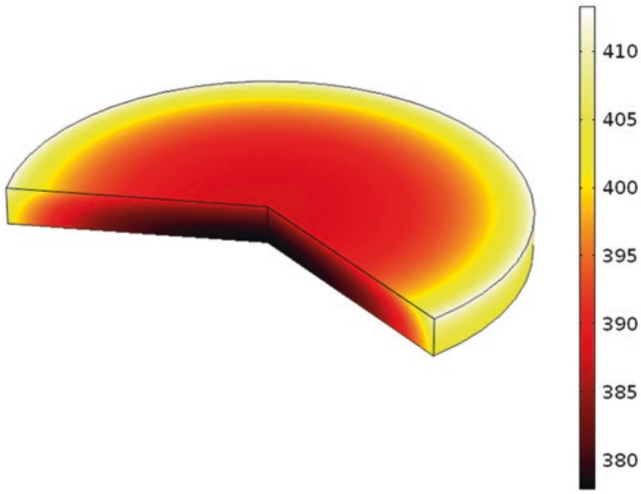

Fig. 8.4 Temperature distribution during thermal processing (temperature in Celsius)

Table 8.1 Effect of cooling rate on the process food quality

Cooling rate	Remarks	Foods
Various cooling rate	Unaffected at various cooling rate	Solid enriched food such as peas, meat with high fat
Minimum 0.5–1.0 °C/min	Unaffected at higher cooling rate	Fish and lean meat
3.0–6.0 °C/min	Quality deteriorate in case of cooing rate less than this range	Egg product, many fruits
Highly thermal sensitive	Cracking can happen at higher cooling rate	Fruits such as tomatoes, cucumbers, raspberries

2.1.2 Process Temperature

Similar to heating rate, processing temperature in preservation techniques such as drying, smoking, and canning is vital. Many a time, people do not care about the processing temperature and rather apply heat energy arbitrarily. People of developing countries just confirm whether the air is hot or not. Literally, they do not care about the temperature of the preservation system. Appropriate preservation temperature varies between foods and nature of processing. For example, drying of fruits and vegetables requires a condition with 40–60 °C for effective moisture removal. Therefore, the available ambient air temperature during sun drying is not suitable for effective drying. Switching to solar drying or addition of other drying systems at the critical stage of drying can solve this problem [8, 9].

When the liquid water absorbs an adequate amount of energy to change its phase to gaseous form, then evaporation occurs. Moreover, high-temperature air will be capable of holding a comparatively excessive amount of water vapor. As a result, a higher rate of evaporation will be experienced with the regions having high temperatures.

Moreover, variability of the required storage temperature should be kept in mind. As storage temperature varies between different varieties of food, the appropriate temperature must be maintained for a specific food product. Proper knowledge of the required temperature is essential to overcome over/underprocessing of food. In addition, temperature measurement and monitoring facilities need to be incorporated in existing preservation system.

Moreover, minimal application of thermal processing is highly expected as thermal processing deteriorates various notorious attributes. As there are many thermal sensitive nutrition present in food materials, degradation of those nutrition can occur during thermal treatment. Inferior appearance of the preserved food may be observed if the food is processed at a higher temperature. Mechanical damage such as burning and chilling also can happen through the application of improper heating. Therefore, bare minimum heat treatment can provide fresh-like preserved food materials.

2.1.3 Temperature Fluctuation

Fluctuation of temperature is generally not good for foods. However, an alternative to the application of heating and cooling sometimes provides the expected good quality of food. For example, high-temperature treatment such as water dipping prior to freezing of refrigeration can be a preventive measure of the excessive chilling effect of food materials. In addition to thermal processing, fluctuation of temperature can cause an adverse effect in food storage. For example, condensation of moisture may happen in food storage system and even in packaging systems due to frequent fluctuation of temperature. Therefore, the nature of food preservation needs to be taken into consideration before applying fluctuating heating rate.

Moreover, temperature is one of the vital parameters of other nonthermal food preservation techniques. Although the preservation does not require heat to prevent microorganisms, temperature affects different parameters of various processes significantly. For example, salt uptake by food during salting process can significantly be increased with the increase of temperature [10]. Similarly, many chemical processes accelerate at a higher temperature in different process such as fermentation, pickling, and jamming. However, there exists an optimum process and product-specific temperature. Special care must be taken while selecting the preservation temperature.

Moreover, the respiration rate and the rate of the microorganisms growth in the product are profoundly affected by the temperature [11–15]. By maintaining the colder food chain, the growth of microorganisms can be slowed down which might help to increase the shelf life along with retaining the finest quality.

Storage temperature for fruits, vegetables, and grains significantly varies with the types of products [16–18]. For example, storage temperature for crops in the winter and summer season ranges from 0 °C to 1.67 °C and 4.44 °C to 12.78 °C, respectively [19]. Table 8.2 represents the appropriate storage temperature of some selected fruits, vegetables, and grains [19, 20].

In summary, the equipment, devices, and utensils must be selected on the basis of their thermal properties especially when thermal processing is involved in food preservation chain. Inappropriate thermal properties are not favorable for energy-efficient system.

2.2 Mass Transfer

Overall, most of the foods have more complex material based on their physical characteristics than the solid crystal materials. Moisture content, water distribution, and water activity are vital in the proliferation of microorganisms. Most of the food preservation techniques deal with these water-related parameters of foods.

Reduction of water content results in decreased water activity which is not conducive to proliferation of microorganisms. In order to transfer water, different forms of energy including heat, mechanical, sound, and electromagnetic energy are

Table 8.2 Appropriate storage temperature of some selected fruits, vegetables, and grains

Commodities	Temperature range (°C)	Example
Fruits	(−0.56)–0	Apricot, blackberries, blueberries, dewberries, currants, elderberries, gooseberries, raspberries, strawberries, grapes, nectarines, peaches, cherries, plums and prunes, quinces, pomegranates
	(−1.11)–4.44	Apple, cranberries, coconut, lemons, lychees, tangerines
	3.33–14.44	Mangoes, guava, limes, olives, orange, papayas, pineapples, banana, watermelon
Vegetables	(−1.11)–0	Artichokes, beans, beets, broccoli, Brussels sprouts, cabbage, carrots, cauliflower, celeriac, celery, chard, chicory, collards, corn, garlic, greens, kale, kohlrabi, leeks, lettuce, mushrooms, onions, parsley, parsnips, peas, radishes, rhubarb watercress, rutabagas, salsify, spinach, turnips, watercress
	2.78–10	Dry beans, green beans, lima beans, crenshaw, honey dew, Persian, okra, chili peppers, potatoes, squashes
	10–15.56	Cucumbers, jicama, sweet peppers, pumpkins, sweet potatoes, tomatoes, squashes
Grains	4.44–25	Barley, buckwheat, corn, oats, millet, peanuts, rye, soybeans, sorghum, wheat, alfalfa, clover, crown vetch, tall fescue, orchard grass, ryegrass, Timothy

Adapted from Gast [19] and Part [20]

provided. However, maintaining moisture concentration gradient between the food and the surrounding by any means can cause water transfer from the food. Several types of internal moisture transport mechanisms take place during food preservation. However, depending upon the process condition and food properties, different types of internal moisture transfer mechanisms can dominate during the techniques.

The internal moisture transport takes place using three transport mechanisms:

(i) Transport of free water
(ii) Transport of bound water
(iii) Transport of water vapor

In general, at high moisture contents, liquids flow due to their dominating capillary forces. With decreasing moisture content, the amount of liquid in the pores also decreases, and a gas phase is built up, causing a decrease in the liquid permeability [21]. Gradually, the mass transfer is taken over by vapor diffusion in a porous structure, with increasing vapor diffusion as shown in Fig. 8.5.

To keep the freshness of the raw plant-based food materials intact, a high relative humidity ranging between 80% and 90% is suitable [22]. Different selected fruits, vegetables, and grains are illustrated in Table 8.3 with their appropriate storage relative humidity [19, 20]. In the case of dried fruits, vegetables, and grain storage, the relative humidity should be maintained at a controlled rate. As the insects and the microorganism cannot grow in the dried foods with the moister content around

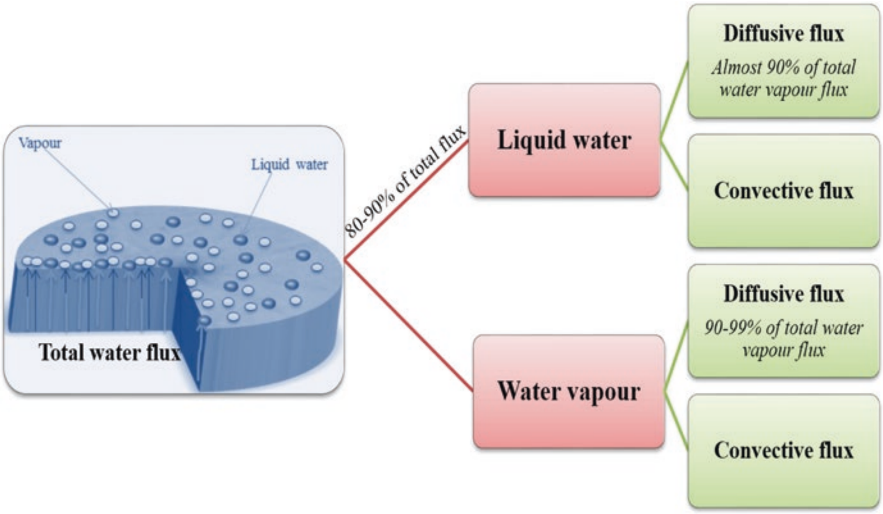

Fig. 8.5 Water migration from food during different preservation techniques

Table 8.3 Appropriate relative humidity of some selected fruits, vegetables, and grains

Commodities	Relative humidity range (%)	Example
Fruits	75–85	Coconut, dates, grapes
	85–90	Mangoes, lemons, limes, nectarines, olives, orange, papayas, pomegranates, guava, quinces
	90–95	Apple, apricot, blackberries, blueberries, cranberries, dewberries, currants, elderberries, gooseberries, raspberries, strawberries, cherries, peaches, pears, plums and prunes, lychees, pineapples, tangerines, banana
Vegetables	50–70	Jicama, garlic, chili peppers, pumpkins, squashes
	90–100	Artichokes, asparagus, beans, beets, broccoli, Brussels sprouts, cabbage, carrots, cauliflower, celeriac, celery, chard, chicory, collards, corn, cucumbers, greens, mushrooms, okra, onions, parsley, parsnips, peas, sweet peppers, potatoes, radishes, rhubarb watercress, rutabagas, salsify, spinach, squashes, tomatoes, turnips, watercress
Grains	6.7–15.5	Barley, buckwheat, corn, oats, millet, peanuts, rye, soybeans, sorghum, wheat, alfalfa, clover, crown vetch, tall fescue, orchard grass, ryegrass, Timothy

Adapted from Gast [19] and Part [20]

10–12%, the relative humidity should be below than the mentioned range. However, the moisture content should be maintained at 2% or below in the case of prolonged storage [20]. For these cases, special packaging system can be accommodated to maintain the proper moisture level of the foods.

Similarly, the rate of cooling effect is directly proportional to the evaporation rate. The humidity of the surrounding air has a high impact on the efficiency of the evaporative cooler. It is essential to maintain the process conditions if they are not favorable. If the relative humidity is low, a significant amount of liquid water changes into water vapor, provided that all the other conditions are fulfilled. Conversely, if the relative humidity is high, the rate at which water evaporates will be low, and eventually, a reduced cooling effect will be attained.

As water distribution is the prime factor in increasing shelf life of food, special care must be taken in choosing process parameters. Food preservation especially drying, salting, and smoking involves migration of water to decrease water activity. Therefore, the preservation conditions need to be maintained properly to remove water from food materials efficiently.

2.3 Chemical Reaction Kinetics

Different forms of chemical reactions take place during food preservation. Many unwanted chemical reactions happen due to improper process conditions. These unexpected reactions deteriorate food quality to a significant extent. In many preservation techniques such as fermentation and jamming, concentration of key components including sugar, salt, and acid plays a vital role via hindering the growth of microorganisms. For example, the inhibition of unexpected enzyme activities, slowing down alcoholic and lactic fermentation, depends on the concentration of salt [23, 24].

On the other hand, the expected level of certain reaction depends on process condition. For example, the optimum amount of Maillard reaction between amino acid and sugar happens at an elevated temperature during thermal treatment.

Moreover, certain chemical kinetics result in an unexpected ripening of fruits and vegetables. For example, the foods emit ethylene gas that can accelerate the ripening of other foods. Therefore, separate sections should be dedicated to those ethylene-emitting fruits and vegetables.

2.4 Presence of Air

The presence of air and air velocity remarkably affect the performance of different food preservations. Oxygen is vital for the proliferation of microorganisms. The absence of air results in an insufficient amount of oxygen available for microorganisms. Moreover, the presence of air is not favorable for many food preservation systems including freezing. Uniform formation of crystal is hindered by trapped air and metabolic gases; hence pretreatment balancing is required prior to freezing. On the other hand, some preservation techniques such as fermentation and pickling require a certain amount of oxygen for the growth of expected bacteria and other microorganisms. Therefore, the access of air should be maintained according to the demand that varies between preservation techniques.

2.4.1 Presence of Oxygen

The optimum level of respiration also depends on the access of air in stored food materials. Fruits and vegetables are living tissues and they respire like other living species [25]. Respiration rate is important for the growth as well as for extending the storing life. The respiration and metabolic rate are directly influenced by the room temperature and availability of oxygen [26, 27]. Fruits, vegetables, and grains can be classified by their respiration rates, which is depicted in Table 8.4 [19, 28]. It is better to slow down the respiration rate rather than to stop it permanently. Implementing this phenomenon, most of the vegetables and fruits are wrapped in plastic to allow their respiration rate at a moderate level [29, 30].

2.4.2 Air Flow Rate

The velocity of air is crucial for some preservation technique including drying, smoking, as well as storage of food. Air velocity mainly denotes the mass flow rate of moisture and oxygen. Similar to heat, an optimum air flow rate needs to be maintained to attain adequate amount of oxygen supply for a system. An adequate amount of oxygen is essential for complete burning of wood or other solid fuels during smoking.

Uniform distribution of air needs to be ensured in order to accomplish different food preservation techniques. Many a time, nonuniform air velocity in grain drying

Table 8.4 Fruits, vegetables, and grains are classified by their respiration rates

Commodities	**Respiration rate** (Btu/ton/24 h) **at 5 °C**	**Example**
Fruits	<5	Nuts, dates, dried fruits
	5–20	Apple, grape, apricot, cherry, pear, plum, nectarine
	20–60	Strawberry, blackberry, artichoke
Vegetables	5–20	Garlic, onion, potato, sweet potato, cabbage, carrot, lettuce, pepper, tomato
	20–40	Lima bean, raspberry, cauliflower, green onion, Brussels sprouts
	>60	Sweet corn, mushroom, spinach, pea, broccoli, asparagus
Commodities	**Respiration rate** r_{co2} (mg co_2)/(kg.h) **at 0 °C**	**Example**
Grains	0.08–5.7	Barley, oats, corn
	1–66.3	Rice, flax, soybean, wheat

Adapted from Gast [19] and Sood [30]

causes uneven moisture removal and causes a significant waste of grain. Similarly, the uneven supply of oxygen during smoking foods causes hot and cold zones in food materials. Therefore, air supply at an adequate rate along with uniform distribution needs to be confirmed in order to attain a uniform quality of preserved food materials.

In addition to this, air velocity is vital for the process involving moisture migration from foods. When evaporation occurs, the humidity of air rises closest to the surface water. If the velocity of air is relatively lower, the rate of evaporation will be slowed down. In contrast, if the humid air is continuously replaced by the dry air, which is only possible if the movement of air is high, then the evaporation will increase promotionally with the velocity of the air.

In addition to this, clean air should be ensured in all aspect of food preservation. Air can carry both harmful chemicals and microorganisms [31]. It is recommended to assess the air quality of a locality prior to establishing food preservation facilities.

2.5 Shape, Size, and Contact Surface

Most of the physics happened during food preservation are significantly affected by the shape and size of food as well as the system. The combined effect of size and shape can be expressed in terms of the compactness as it considers both volume of the sample and the exposed surface area. Therefore, the compactness of the food sample and the equipment-associated preservation need to be considered properly.

Compactness of raw food varies between types. Appropriate cutting needs to be ensured in order to speed up the preservation process. Smaller piece of food can be processed faster than the larger one. For example, a larger piece of food takes more time to dry than thinner one. Likewise, heat transfer and mass transfer are also significantly affected by the size and shape of the food. For instance, salt untacking from surface to the center takes significantly higher time for thicker fish fillet [10]. However, considering the quality and energy consumption of preparation, a moderate size needs to be maintained.

Similar to sample compactness, the utensil, equipment, and devices used in food preservation techniques must be taken into consideration. A system that allows a higher contact area toward the food provides faster processing. For example, the contact surface of ice with fish is vital during preservation. Higher contact surface area means more effective cooling. In order to maintain maximum contact surface, the ice needs to be crushed into small pieces.

Therefore, high attention needs to be paid in designing the system for optimum shape and size. Contact surface area must be designed in such a way that offers maximum flux of heat and mass transfer.

2.6 Material Selection

Material selection plays a vital role in the effectiveness of preservation techniques. Physics-oriented properties vary between materials. Wrong selection of materials may cause a higher consumption of energy and degrade the quality of foods. In many cases, inappropriate materials can spoil preserved foods as well as make the food unhygienic.

Insulating material selection is important in food storage, refrigerator as well as packaging. Improper insulation material not only negatively affects food storage efficiency but also adds extra energy consumption. The traditional plant-based insulator can be replaced by the latest plastic-based insulator due to its high durability in adverse weather [32].

2.7 Light

Light is one of the catalysts of different chemical reaction during different types of food preservation techniques. Light with certain intensity causes photolytic and photocatalytic reaction in different food materials. Different groups of food are susceptible to photodegradation in varied extent when directly exposed to light. Photodegradation accelerates the chemical reaction in the food and thus remarkably affects the pigments, vitamins, fats, protein, and flavor of the food. The measurement of the sensitivity of the foods to the exposure that cause photodegradation depends on a number of factors including light type, intensity, the wavelength of the light, the oxygen content of foods, and packaging properties. For example, milk and milk-based products are highly sensible in photodegradation [33].

For high-intensity light pulse (HILP), the high-intensity broad-spectrum wavelength distribution ranges from 100 nm to 1100 nm. Pulses of light used for food processing and storage applications typically emit 1–20 flashes per second at an energy density ranging from 0.01 J cm^{-2} to 50 J cm^{-2} at the surface [34, 35]. Artificial light with low intensity such as fluorescent tube can be used.

All of the underlying physics takes place during diverse food preservation focused on either prevention of microbial proliferation or prevention of chemical reaction or inactivation of the enzymatic reaction. A slight variation of associated process parameters may vary the effectiveness of the preservation to a significant extent. Taking all of the physics into consideration, choosing the appropriate process conditions is the most important concern in overcoming the challenges and mistakes. Design and modification of the preservation system should be based on the basis of the underlying physics that takes place during food preservation. It is well established that preservation conditions significantly affect the energy consumption, quality, and processing time as shown in Fig. 8.6.

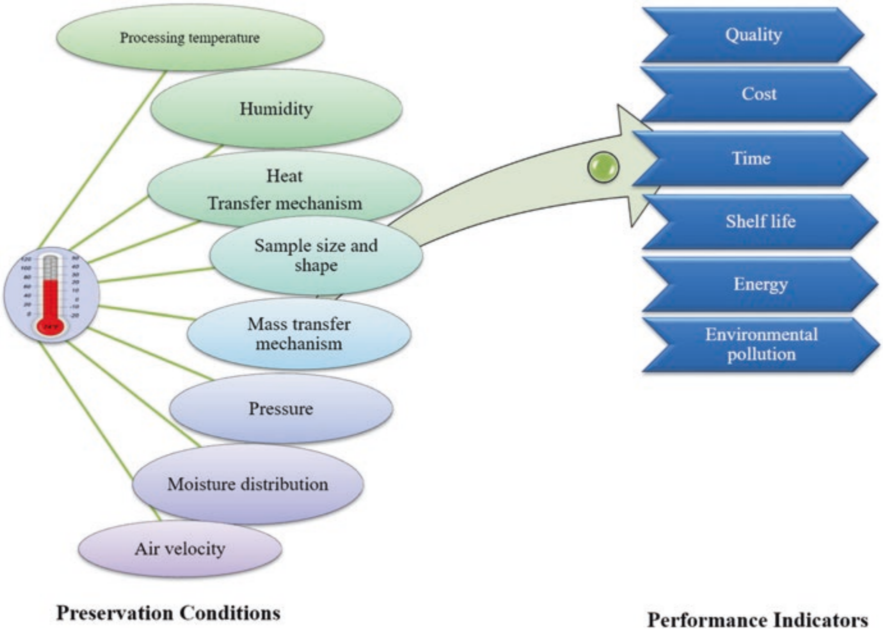

Fig. 8.6 Correlation between preservation parameters and performance indicators

3 Awareness and Motivation

A combination of proper dissemination of updated information and motivation campaign is an effective measure to overcome many challenges and mistakes in connection with the food preservation techniques.

Due to the lack of awareness, people make a lot of mistakes on a daily basis. Through motivational campaign, people can be informed of the solutions for the common mistakes that take place in food preservation in rural areas. These people, often, have no access to such counselling facility where they can share their problems. The campaigns can then be treated as a mobile counselling center for the rural people. A set of different strategic information propagation would result in a great reduction in food preservation mistakes. Different forms of media including electronic media, radio, newspaper, poster, and billboard can be incorporated simultaneously for information dissemination [36].

Moreover, consumer awareness is also essential to enhance the propagation of right approach and quality maintenance of preserved food. Even students at different levels need to be informed of the basics of food preservation. The consumer can contribute significantly in developing awareness of the people involved in food preservation.

Motivation is as important as awareness regarding food preservation. Both consumers and food preservation personnel need to be motivated for sustainable food preservation. Many a time, educated young people do not show interest toward involving in food preservation-related occupation. This may be due to the sociocultural status of the food preservation-related works. In many developing countries, agriculture-related works are treated as one of the lower-level activities. It is even classified as poor people's or illiterate persons' work. Consequently, young educated people of developing countries think they cannot afford their necessity through food preservation-related works [37, 38]. Therefore, motivation campaigns need to be arranged regularly to expose the potential benefits of involving in food preservation-related occupation.

4 Research

Research must be conducted to figure out the major loopholes in food preservation techniques in developing countries. Multidisciplinary researchers can carry out research in different aspects of the local food preservation techniques. Considering the diversification of challenges and mistakes that take place in food preservation in developing countries, there is no one-size-fits-all solution. Due to these diversifications of the approaches of a particular food preservation technique in different countries, exclusive research needs to be carried out for traditional techniques [39].

Firstly, researchers can focus on the better utilization of the available resources along with minimal modifying indigenous approaches. Many a time, people show no interest due to fear of losing their indigenous knowledge of adapting technology in the existing system. A promise of minimum and necessary modification can attract the rural people to adopt research findings in their practicing approaches.

Secondly, researcher should make the new technologies understandable and applicable to the rural people. Many a time, technology is not easy to be implemented by an ordinary person [40, 41]. For general people, which technology is adaptable for their particular food preservation technique is not clear. Therefore, there is a huge research potential for simplifying the latest technology for the rural people. In particular, the cost and benefit analysis in adopting latest technology technologies is the vital sector of investigation [42, 43].

Thirdly, quality assessment of the traditionally preserved food is not regularly investigated. Extensive research needs to be carried out to examine the quality of preserved foods. Development of easy and applicable guidelines to maintain good quality food also requires thorough research.

Research needs to be carried out in order to assess the effectiveness of different traditional approaches. If the practicing strategy is effective enough, no significant modification will be required. For example, commercial pesticide should not be introduced instead of local pesticide option such as neem leaves or wood ash in storage system [43–48].

Finally, dissemination of the research findings to the farmer level must be ensured to get the highest benefit of the research. Many a time, successful researches are left at the laboratory level and confined to the academician and researchers. Appropriate steps of commercialization of local food preservation-related research must be taken into consideration. These types of research cannot contribute to solving root-level problems encountered by rural people.

5 Education and Technical Training

People execute food preservation in developing counties with traditional knowledge (TK) that passed from generation to generation. The TK sometimes can be science as these are developed from continuous observation, examination, and implementation [49]. On the other hand, technical knowledge is enriching day by day and becomes difficult to comprehend by rural people. Therefore, individuals need systemic education to grasp the basic of food preservation techniques as most of the people in developing countries who are engaged in food preservation activities cannot either read or write [50].

Basic science and concepts of traditional food preservation can be included in the course curriculum in different levels of the educational system. Even older people can be educated from very basic to advance level with an appropriate initiative of interactive teaching method. People are familiar with practical aspects; little improvement in basic knowledge may make a huge difference. On the other hand, the main constraint of adaptation of technology in the traditional system is inadequate and deprived of basic scientific knowledge. Especially, the mistakes in traditional food preservation cause defective final product which needs to be focused during different training sessions [36].

Moreover, the business skills need to be introduced in the individual and small group level to promote and commercialize their preserved food. In this way, they can contribute more actively in national economics. Several related skills including numeracy for basic bookkeeping, self-confidence, willingness to take risk, communication, and adaptation with the demand of time need to be taught to the rural people [51, 52]. Due to the lack of professionalisms, many good quality preserved food are not getting the expected market values. Furthermore, enhanced skills such as planning and administration and negotiation and marketing need to be developed for the people engaged in small-scale to large-scale production.

Technical support is one of the overlooked aspects of solving food preservation-related challenges. Slight counselling and support can make a huge difference in many cases. A team of potential people can be trained in common mistakes, challenges, and their solution which in turn educate others effectively. There should be both long- and short-term human resource development programs available for the rural people. The trainings need to be collaboratively facilitated by the government and NGOs.

6 Renewable Energy Incorporation

Sufficient energy access is the main challenge in solving food preservation-related problems in developing countries. Most of the thermal preservation techniques such as drying, smoking, and pasteurization take fossil fuels, whereas refrigeration and freezing use high-grade energy like electrical energy [53]. Both fossil fuel and electrical energy utilization cannot be a sustainable solution for developing countries. Most of the regions of rural areas in developing countries do not have access to the national grid electricity.

These food preservation systems in developing countries mostly depend on nonrenewable source of energy, which is a major drawback for developing and least developed nations with a dire crisis of energy. In other words, application of combined solar, geothermal, and wind energy can sustainably solve the energy-related problem in food preservation sectors in developing countries. Along with exploring renewable energy resources, energy storage systems need to be introduced [54].

Moreover, biogas and biofuels yielding from nonedible part of the plant may be one of the potential sources of energy to the rural people [55]. Food waste also can be used as the feed in the energy conversion systems.

Evaporation cooling would be one of the energy-saving approaches in food storage system. People with limited resources can get the effect of refrigeration with a very low cost. This process does not require any conventional energy to get the refrigerant effect.

Therefore, an initiative to finding feasible sources of renewable energy must be taken into consideration from the public and private sectors associated with food preservation techniques.

7 Financial Support

As young people are not interested in agro-based occupation, they must be supported with financial aid to adopt technology in traditional food preservation system.

Most of the cases, electricity and pure water are not accessible to rural people. Many a time, people use highly contaminated water from well or other open-surface water. Financial support in reducing electricity and pure water price is crucial to adopt new technology as well as maintain high-quality food [36].

Rural people generally do not have enough initial capital which is required to start a food preservation system. Financial incentive is important for both individual and small-scale enterprises of food preservation. Even small financial support can encourage poverty-prone food producers to an appreciable extent. Government loan with zero interest rate would highly encourage people to get involved in food preservation occupations.

8 Technology Transfer

Technology transfer means eliminating difficulties encountered during traditional food preservation techniques. It does not alter the sociocultural values of the indigenous techniques. Moreover, the incorporation of sustainable modern techniques enhances the yield significantly. In other words, the process takes a remarkably low time compared with its traditional counterpart. In addition, less manual ensures high quality of preserved foods.

One of the constraints in adapting technology in rural food preservation system is the high price of tools and equipment. Technological initiatives need to be taken to develop cost-effective technical stuff which can utilize local resources. Therefore, the viable and economically feasible technology should be transferred to household and industrial sectors.

Devices in connection with different parameter measurements need to be economically affordable to the rural food producers. Many a time, failing to measure the preservation parameters results in a substantial amount of loss. Therefore, special attention needs to be given in the development of cost-effective measuring and control devices related to food preservation systems.

As the level of technical understanding varies between people of different countries, special care should be taken in choosing technology transfer approach. The complexity of updated technology should be translated at the level of farmers' for their better understanding.

In a nutshell, a wide range of solution options including the abovementioned ones needs to be pursued simultaneously. In order to do so, cooperation among people involved in food preservation, NGOs, and government is essential. In a broad sense, the implementation of the solution approaches is interrelated and depended on the contribution of different sets of people.

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Chapter 9
Feasibility of Advance Technologies

Abstract Many of the traditional food preservation techniques offer an effective solution to food waste. However, there are many challenges that can be solved easily with the incorporation of modern technology. With the advancement of technology and better understanding, food preservation techniques are being changed day by day. Incorporation of feasible innovative technique can solve the challenges and enhance the overall performance of food preservation technology in developing countries. Although modern techniques offer enormous advantages, prior viability analysis must be conducted prior to incorporation in developing countries instead of traditional ones. Different constraints such as financial, technological, and environmental need to consider preceding of changing and modifying traditional food preservation technique. Therefore, the optimization of advanced technology must be analyzed before implementing modern technology in food preservation in developing countries. In this chapter, the feasibility of some potential advanced technologies in connection with food preservation has been discussed in this chapter.

Assessing the likelihood of any proposal is the key aspect related to the feasibility study. To be feasible, a proposed technique must fulfill a maximum of the relevant factors including economical, ecological, technological, and legal. There are numerous food preservation techniques that are practiced in the developed countries, but the developing world is far behind from these techniques due to several unavoidable circumstances. Although some of the developing countries accommodate some modern food preservation system, their contribution to overall food preservation is still at an insignificant level. Some potential technologically advanced tools related to food preservation which can be adapted in developing countries have been discussed briefly in the following sections.

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1 Drying

There are different common drying techniques such as sun drying, spray drying, hot air drying, and solar drying. Beside these drying techniques, there are some advanced techniques in the field of drying that may offer quick drying by sustaining better quality of the dried food. Figure 9.1 shows some of the selected advanced drying approaches.

1.1 Improved Solar Drying

In solar drying system, food is placed in an enclosed chamber. This enclosed chamber ensures the safety of foods from the outside damage and contaminations caused by birds, insects, dust, and unexpected rainfall. It is one of the most economical drying systems as the system totally depends on the renewable energy to run. However, to keep it stand alone for 24 hours is a challenging task, because of the unavailability of solar energy at the night. Moreover, there is a great lacking of system optimization in the conventional solar dryer. To overcome these issues, numerous researches have been conducted in different arenas of the globe [1–4].

To make the solar dryer functional in the off-sunshine hours, two modern technologies have been introduced, namely, desiccant units and thermal storage systems. By introducing these approaches, continuous solar dryer system can be established. The thermal energy storage can be formed in different means which is represented in Fig. 9.2 [5]. There are different forms of thermal energy storage, but the latent heat of solid-liquid combination provides the best output. A list of selected solid-liquid materials along with their temperature range, density, and specific heat is extensively represented in Table 9.1.

Although numerous researchers have tried to contribute in designing and fabricating of improved solar dryer by introducing phase change materials, the most recent work has been accomplished by Bal et al. [6]. In this study, paraffin wax had been used as a phase change material (PCM) that acts as a latent heat storage (LHS).

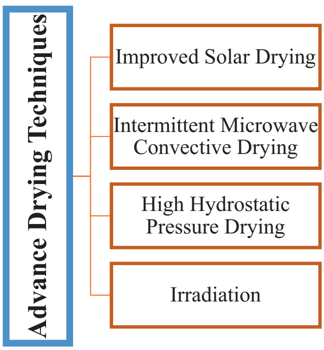

Fig. 9.1 Advance drying techniques

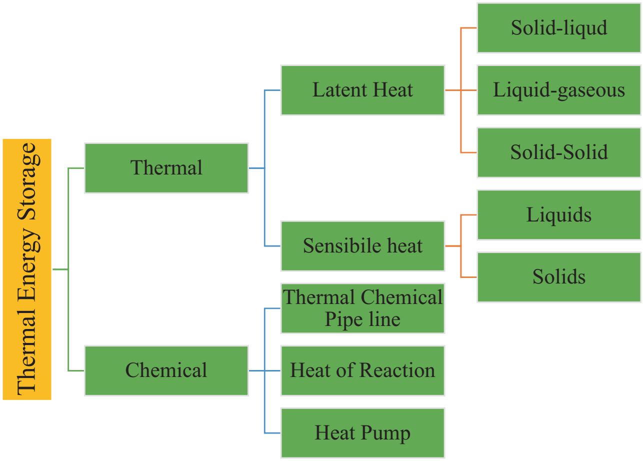

Fig. 9.2 Different types of thermal storage of solar energy. (Adapted from Bal et al. [6])

Table 9.1 A list of selected solid-liquid materials for sensible heat storage [7]

Medium	Fluid type	Temperature range(°C)	Density(kg/m^3)	Specific heat(J/kgk)
Rock		20	2560	879
Brick		20	1600	840
Concrete		20	1900–2300	880
Water		0–100	1000	4190
Calorie	Oil	12–260	867	2200
Engine oil	Oil	Up to 160	888	1880
Ethanol	Organic liquid	Up to 78	790	2400
Propanol	Organic liquid	Up to 97	800	2500
Butanol	Organic liquid	Up to 118	809	2400
Isobutanol	Organic liquid	Up to 100	808	3000
Isopentanol	Organic liquid	Up to 148	831	2200
Octane	Organic liquid	Up to 126	704	2400

Paraffin wax enables to store excess solar energy all through the daytime and utilized this stored energy. This system helps to reduce the dependency on the supplementary energy sources when there is inadequate or unavailable solar energy. Consequently, the improved solar dryers offer continuous, steady, and moderate-temperature drying at a temperature range of 40–75 °C. Figure 9.3 shows the fabricated improved solar dryer [6].

There are several types of improved solar dryer available in developed countries, and sometimes choosing an appropriate kind of dryer for developing countries can become a confusing job. Local research must be conducted prior to introducing these modern solar drying systems. Many factors including solar intensity, availability, and cost are needed to be considered.

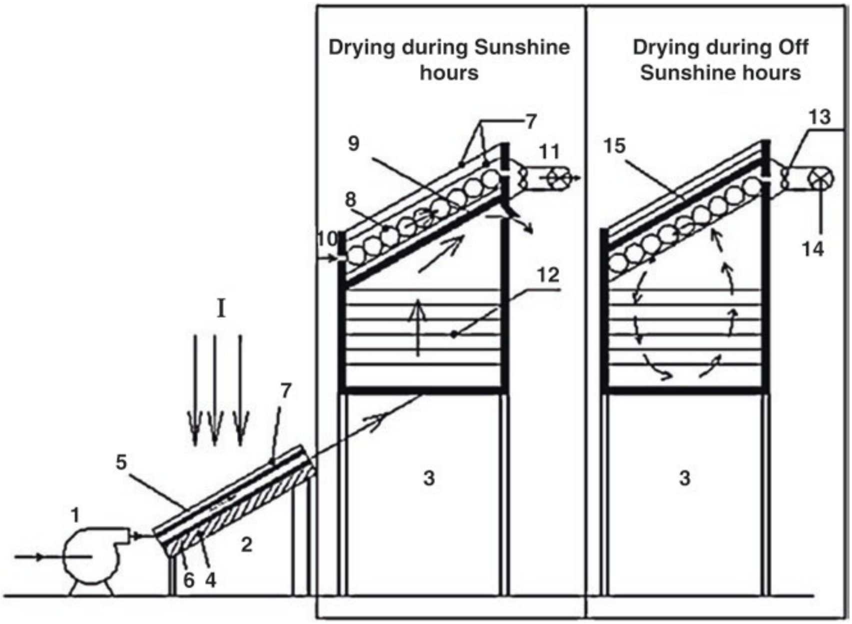

Fig. 9.3 (**a**) Schematic of the desiccant integrated solar dryer [6]. 1 Blower, 2 flat-plate solar air collector, 3 drying chamber, 4 insulation, 5 absorber plate, 6 bottom plate, 7 transparent cover, 8 desiccant bed, 9 plywood, 10 air inlet, 11 duct for air exit, 12 drying trays, 13 reversible fan, 14 valve, 15 plywood

1.2 Intermittent Microwave Convective Drying (IMCD)

Microwave drying is a novel technique of heating food materials. Microwave penetrates the food material until moisture is located and heats up the material volumetrically and increase of pressure gradient drives the moisture from the inside of the material [8]. For a commonly used microwave frequency of 2450 MHz, the electric field changes directions 2.45 billion times a second, making the dipoles move with it [9]. Such rotation of molecules produces friction and generates heat inside the food material [10]. Fruits and vegetables contain about 80% of dipolar water. Consequently, significant amount of volumetric heat developed during microwave heating.

Continuous microwave is not a good option of food drying due to its nonuniform heating. Intermittent application of microwave along with continuous hot air drying can solve the problems of both microwave and hot air drying Moreover, intermittent drying has been considered as one of the most energy-efficient drying processes [11]. Intermittent drying is a drying method where drying conditions are changed with time. It can be achieved by controlling the supply of thermal energy by varying the airflow rate, air temperature, humidity, or operating pressure and also the mode of heat input. Energy analysis in intermittent drying of yerba mate [12], squash slice [13], grain [14], kaolin [11, 15], and *Ganoderma tsugae* [16] demonstrated that intermittent drying is more energy efficient than continuous drying (Fig. 9.4).

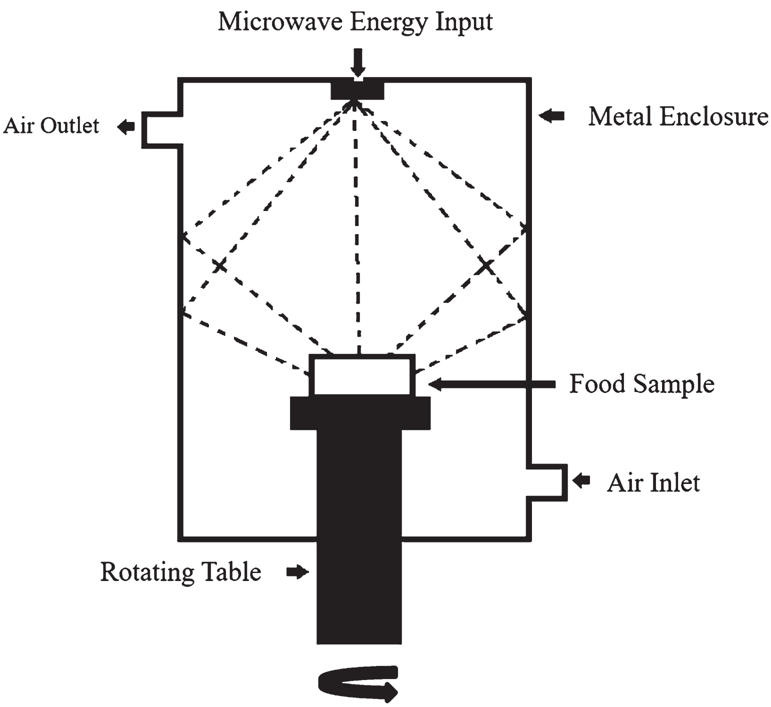

Fig. 9.4 Multimode applicator with mode stirrer and turntable [17]

The main working principle of the intermittent microwave convective dryer is that when food is introduced into the drying chamber and the chamber is closed, then at first the intermittency is fixed and entered into the input section of the control system. When the process begins, microwave helps the bound water to move from intracellular spaces to intercellular spaces, and the continuous mode helps to dehydrate the food material by convecting away the moisture in the form of mass flux. Intermittency should be selected based on heat and mass transfer involved in the particular drying process and material properties of the product to be dried.

Advantages of IMCD in terms of improving energy efficiency and product quality and significantly reducing drying time have been found in many products such as sage leaves [18, 19], bananas [20], oregano [21], pineapple [22], red pepper [21], and carrots and mushrooms [23]. The summary on the research of PMSD has been extensively represented in Table 9.2.

The design of a typical IMCD setup has been represented in Fig. 9.5. There are a lot of advantages of IMCD such as it reduces the degradation of essential nutrients, increases the sensory and nutritional quality of the processed food by IMCD, increases the frequency of high-energy transfer, has low maintenance cost, and is environmentally friendly.

Table 9.2 Summary of research regarding PMSD

Sl. no.	Year	Author	System approach/ methodology	Property measured	Limitations	Ref.
01	2009	Soysal et al.	Finding the effectiveness of various microwave-convective drying treatments of red pepper and comparing to convective air drying. Also comparing between IMCD and CMCD	1. Drying kinetics 2. Physical properties (color and texture) 3. Comparison between IMCD and CMCD	1. Power analysis 2. Temperature distribution	[24]
02	2014	Chandan et al.	Development of an intermittent microwave heating model considering Maxwell equations and variable dielectric properties. Validation of the model comparing the temperature distribution obtained from a TIC (thermal imaging camera) and simulation. Investigation of the temperature redistribution due to intermittency	1. Temperature redistribution 2. Maximum temperature 3. Comparison between experimental and simulation results	1. Theoretical modeling only 2. No microcontroller unit	[25]
03	2009	Yurtsever Soysal	The effectiveness of various microwave-convective air drying treatments was compared to establish the most favorable drying condition of potato in terms of drying time, energy consumption, and dried product quality	1. Drying kinetics 2. Specific energy consumption 3. Sensory properties	1. Not solar assisted 2. No microcontroller unit	[26]
04	2016	João Renato et al.	The drying of pumpkin slices (*Cucurbita moschata* Duch.) by microwave, convective, and intermittent microwave-convective techniques was studied. The samples were pretreated by blanching followed by pulsed vacuum osmotic dehydration. The microwave output power was 780 W	1. Experimental behavior 2. Modeling of drying kinetics 3. Quality analysis	1. Incomplete control unit 2. Not solar assisted 3. No TIC and IC 4. Not innovative	[27]
05	2016	Omid et al.	Drying behavior of lemon slices was investigated using convective (50 °C, 55 °C, and 60 °C inlet air temperatures), microwave (specific power of 0.97), and combined microwave-convective (specific powers of 0.97 and 2.04 assisted with 50 °C, 55 °C, and 60 °C inlet air temperatures) dehydration methods	1. Drying kinetics 2. Determination of rehydration capacity 3. Modeling of drying behavior	1. Theoretical 2. Not energy efficient 3. No temperature distribution	[28]

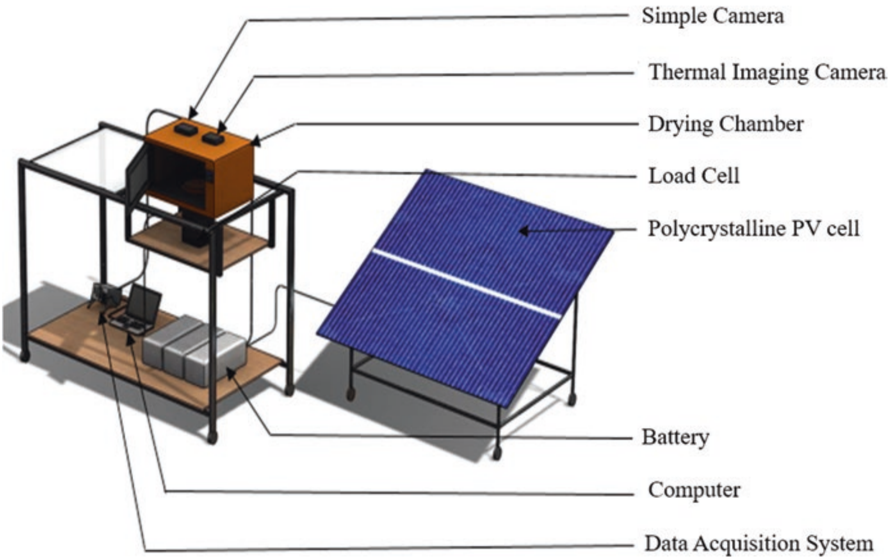

Fig. 9.5 Design of an innovative solar-derived IMCD

Taken all advantages of IMCD, it is one of the most energy-efficient and quality retention-ensuring drying systems. However, there are still some challenges in application of microwave radiation in hot air drying.

1.3 Irradiation

Proliferation of microorganisms is one of the main causes of food waste. Some of the food preservation techniques cause killing of microorganisms [29]. In order to destroy microorganisms, application of ionizing radiation including gamma rays and X-rays is one of the promising options. There is a wide range of advantages of ionizing radiation or irradiation as presented in Fig. 9.6.

Overall shelf life prolongation of food material that is gone through irradiation drying has been found in several researches. For instance, Angel et al. [31] found that no mold was developed in irradiated strawberry samples for up to 2 weeks.

Moreover, irradiation may prolong the shelf life of different categories of seafood stored at low temperatures [30], and optimum radiation doses of 0.75–2.5 kGy may prolong the shelf life by 2–6 weeks at 0–5 °C temperature. Angel et al. [31] and Przybylski et al. [32] studied with irradiated pepper that was stored at 3 °C and observed the shelf life was extended for 6 months. Irradiation not only facilitates to prolong the shelf life, but also it has a wide range of applicability. The different ranges of doses recommended for different purposes are revealed in Table 9.3.

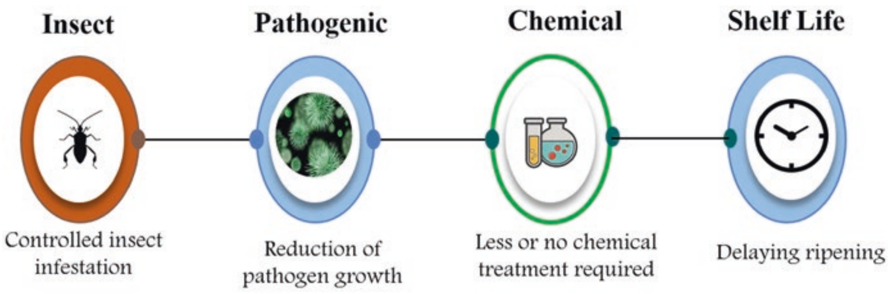

Fig. 9.6 Advantages of ionizing radiation

Table 9.3 Dose ranges recommended for various purposes [31]

Process	Dose range (kGy)
Inhibition of sprouting, e.g., potatoes and onions	0.05–0.15
Delay fruit ripening, e.g., mangoes and papayas	0.2–0.5
Insect infestation, e.g., grain and pulses	0.2–1.0
Elimination of parasites in meat, e.g., *Trichinella spiralis*	0.3–6.0
Reduction of microbial load, e.g., molds on strawberries	0.5–5.0
Elimination of non-sporing pathogens, e.g., salmonella and campylobacter on poultry and salmonella and vibrio on shrimps and prawns	3.0–10.0

Although the application of irradiation process is widely increased, there are still some shortcomings that must need to take into consideration in order to implement it in developing countries. The key issues about the applicability of irradiation are high capital cost, localized risk from irradiation, hazardous operation, poor consumer acceptance, and changes of flavor due to the oxidation process.

1.4 High Hydrostatic Pressure Drying

Thermal energy-associated drying process results in degradation of many heat-sensitive nutrition. To retain these valuable nutrition, high hydrostatic pressure (HHP) is one of the effective techniques. Due to the many distinct benefits of HHP, technologists and manufacturers are extending the application of it in numerous zones of the food drying to generate novel and heat-sensitive food products. There are numerous advantages of HPP that is represented in Fig. 9.7.

Monika et al. [32] investigated the characteristics of convective dried apples along with HHP pretreatment. It is found that HHP pretreatment dried apple shows significantly better result, especially in physical quality.

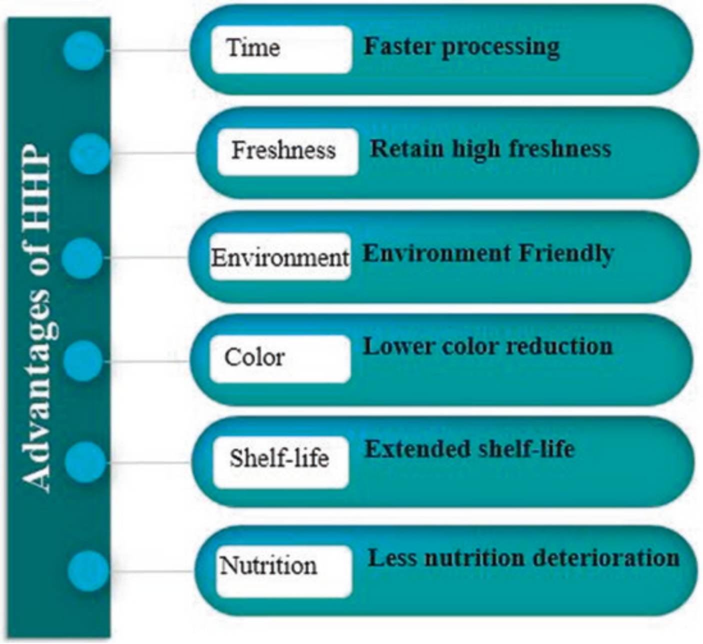

Fig. 9.7 Benefits of high hydrostatic pressure process

Even though the application of HPP process offers several benefits, there are still some challenges that are requisite to take into consideration prior to implementing it in developing countries. The major concerns about the applicability of HPP include:

- Water content in the food is obvious as the process is entirely dependent on compression
- Protein denaturation occurred significantly
- Inappropriate for the inactivation of spores and enzymes
- Discontinuous for solid, viscous, and particulate foods
- Higher initial cost

2 Modified Atmosphere Packaging

In modified atmosphere packaging (MAP), a controlled gas atmosphere is maintained inside the package to reduce microbial growth [33, 34]. This preservation system is generally used for highly perishable product such as fresh meat and fruits, which significantly extend the shelf life Singh, Wani, Saengerlaub, and Langowski [33].

In MAP, to establish a desired gas mixture region and to avoid a buildup of unsuitable gas formation within the package, gas-flushing or gas-scavenging agents are used [35–37]. If unsuitable gases like CO_2 are produced, then free space volume inside the pack will reduce that will subsequently increase the probability of pack collapse [38]. In passive modified atmosphere packaging, CO_2 absorbers are used to inhibit the formation of CO_2. However, extreme enzymatic browning, physiological injuries, and cell membrane damage of packaged food occur if disproportionate growth of CO2 is accomplished [39–41]. If the MAP are prepared properly, then the packaged food shows less respiratory action, softening, and ripening [42]. That subsequently increases the shelf life of the packaged food materials. Figure 9.8 shows the application of modified atmosphere packaging (MAP) for different selected food samples.

In the recent years, MAP is practiced in some developing countries including Nigeria, Bangladesh, and India in order to preserve fruits and vegetables. Performance of MAP in extending shelf life is represented in Fig. 9.9 [43–47].

Fig. 9.8 Practical application of modified atmosphere packaging (MAP)

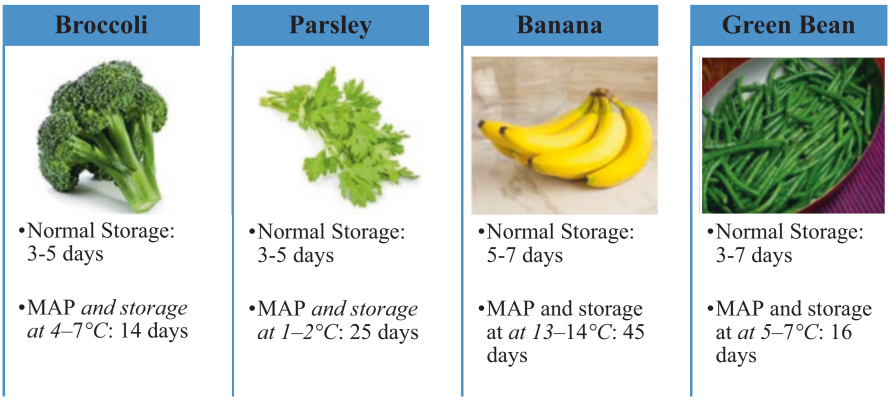

Fig. 9.9 Recent successful implementation of MAP [43–47]

Although the application of MAP offers several advantages, there are still some challenges that need to be addressed prior to implementing in other developing countries. The following are the major concerns about the applicability of MAP:

High initial cost of MAP packaging devices
Pricise temperature control is necessary
Different types of gas formulations are needed for each product type
Special equipment and trained skill are required

3 Application of Ultrasound in Food Processing

The sound waves with the frequency that are away from the limit of human hearing are known as ultrasound. Ultrasound may be applied in numerous industrial applications including food industry by alteration of its frequency. In the recent times, ultrasound becomes an emerging technology in the field of food processing because of its low cost, simplicity, and energy-efficient nature. Moreover, many food ingredients and products are thermally sensitive and vulnerable to chemical, physical, and microbial changes; conventional food processing is not the best choice for those products. There are basically two types of ultrasound having different frequencies used in food preservation system. Applications and outcome vary between types of ultrasound method as presented in Table 9.4 [48–51].

Ultrasound propagates through a biological structure and induces compression and depressions of the medium particles, and a significant extent of energy may be imparted. The intensity and the frequency of the sound in a processing unit depend on the type of application. The potential application of high-intensity ultrasound in

Table 9.4 Distinguished feature of low- and high-power ultrasound systems [48–51]

Types of ultrasound		
Types	Low power	High power
Frequency of ultrasound	High	Low
Application	Monitoring the composition and physicochemical properties of food components and products	Induces mechanical, physical, and chemical/biochemical changes through cavitation
Stage of application	Processing and storage	Extraction, freezing, drying, and emulsification
Outcome	Effectively control the food properties and enhance the food quality	Deactivate the pathogenic bacteria on food contact surfaces and increase the process food quality by using minimum amount of energy

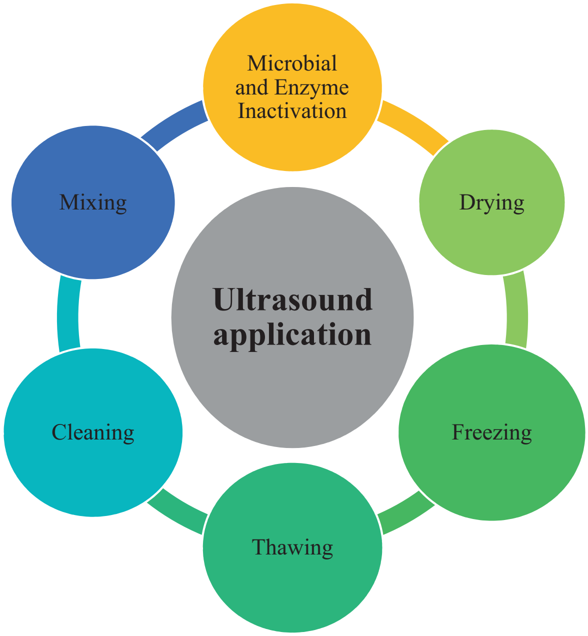

Fig. 9.10 Different applications of ultrasound in food preservation

food processing is represented in Fig. 9.10. Ultrasound is used in one of the following three approaches:

- Direct application to the product
- Coupling with the device
- Submergence in an ultrasonic bath

As the details application of ultrasound in food processing along with their basic principle, advantages are extensively discussed in different literature [48–51], an overview is presented in Table 9.5.

Table 9.5 shows that ultrasound can effectively be used in diverse ways in food preservation. As most of the ultrasound-associated technologies are based on almost similar physics, ultrasonic drying is discussed here briefly.

While ultrasonic energy is combined with hot air in vacuum condition can, intensification of the movement of water molecules take place and facilitates evaporation. Ultrasonic drying can be carried out in low temperature than the conventional drying. This method reduces the probability of oxidation-related degradation of food material. In many cases, ultrasound is utilized as a pretreatment of conventional drying [52, 53]. Application of ultrasound results in micro-channels in food tissue and increases moisture diffusivity. It has been studied that ultrasonic energy coupled with hot air drying reduced the input power to approximately 20% and reduced the time requirement by about 16% in comparison with non-treated ultrasonic drying systems [54–58].

Table 9.5 Applications of ultrasound in food processing [48–51]

Applications	Conventional methods	Ultrasound principle	Advantages	Products
Cooking	Stove Fryer Water bath	Uniform heat transfer	Less time Improving heat transfer and organoleptic quality	Meat Vegetables
Freezing/ crystallization	Freezer Freezing by immersion	Uniform heat transfer	Less time Small crystals Improving diffusion Rapid temperature decreasing	Meat Vegetables Fruits Milk products
Drying	Atomization Hot gas stream Freezing Pulverization	Uniform heat transfer	Less time Improving organoleptic quality Improving heat transfer	Dehydrated products (fruits, vegetables, etc.)
Pickling/ marinating	Brine	Increasing mass transfer	Less time Product stability	Vegetable Meat Fish Cheese
Degassing	Mechanical treatment	Compression-rarefaction phenomenon	Less time Improving hygiene	Chocolate Fermented products (beer, etc.)
Filtration	Filters (membranes semipermeable)	Vibrations	Less time Improving filtration	Liquids (juices, etc.)
Demolding	Greasing molds Teflon molds Silicon molds	Vibrations	Less time Reducing product losses	Cooked products (cake, etc.)
Defoaming	Thermal treatment Chemical treatment Electrical treatment Mechanical treatment	Cavitation phenomena	Less time Improving hygiene	Carbonated drinks Fermented products (beer, etc.)
Emulsification	Mechanical treatment	Cavitation phenomena	Less time Emulsion stability	Emulsions (ketchup, mayonnaise, etc.)
Oxidation	Contact with air	Cavitation phenomena	Less time	Alcohols (wine, whisky, etc.)
Cutting	Knives	Cavitation phenomena	Less time	Fragile products (cake, cheese, etc.)

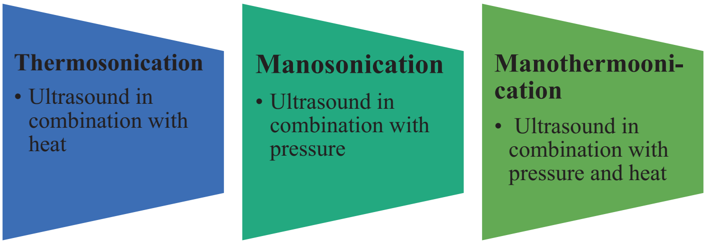

Fig. 9.11 Combined ultrasonic techniques for food processing

Similarly, ultrasound can be combined with other techniques to attain superior quality of processed foods. These combined processes are found to be more effective in inactivating enzymes and microorganisms. Some selected combined techniques that are capable of reducing processing times considerably and have potential for high-energy efficiency are shown in Fig. 9.11.

From the above discussion, it is found that ultrasound can be used as a support of other food preservation process in order to accelerate processing kinetics as well as reduce energy consumption. However, it is not suitable for large-scale preservation techniques.

4 Feasibility of Advanced Technology in Developing Countries

Traditional food preservations have been offering numerous advantages since the prehistoric era. Most of the process is optimized with the countless trial and error of several generations. However, there are some challenges that cannot be solved with the existing traditional technology practiced in developing countries. On the other hand, many advanced food preservation techniques are capable to overcome those challenges effectively. Successful accommodation of advanced technology in developing countries can ensure food security in developing countries. However, proper feasibility analysis must be conducted prior to adopting new technological advancement in developing countries. Some critical factors such as energy, cost, and environmental pollution and other related issues, as shown in Fig. 9.12, must be put into priorities during the consideration of accommodating new technology in developing countries.

Modern technology obviously extends shelf life and quality of processing time along with reducing processing time. However, the following concerns must be taken into consideration prior to incorporating any new technology in developing countries:

- *Cost:* Most of the advanced preservation technologies demand high initial and operating cost. Household or small-scale food preservation systems contribute almost 90% of total food preservation of developing countries. The cost of

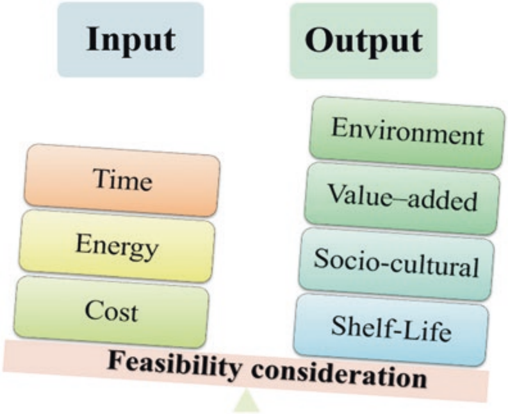

Fig. 9.12 Feasibility-related factors of modern food preservation techniques

modern devices is beyond the capacity of those people. Even governments of many developing countries face the same financial crisis in focusing on modern and sustainable development.

- *Energy:* Advanced food preservation techniques are far more energy efficient than traditional food preservation techniques. However, advanced devices require higher grade energy such as electrical energy. Many of the developing countries still fail to produce enough electricity for a daily necessity such as lighting. Access to electrical energy is one of the constraints in the incorporation of modern food technology in rural areas. One of the possible solutions would be research and application of renewable energy sources.
- *Employment and skilled manpower:* Most of the traditional food preservation techniques are labor-intensive. Even a smaller household food preservation process engages several human hours. Introducing technology-based preservation may reduce the number of employees in developing countries. Therefore, protection of job is a critical issue in implementing automated modern technology in food preservation system. On the other hand, skilled manpower is essential in order to operate advanced devices. Due to the low literacy rate in developing countries, a skilled technical person is not as available as in developed countries. Therefore, enhancing the capacity of the employees or rural person can be one of the solutions of these controversial issues.
- *Environmental pollution:* Utilization of any form of fossil fuel causes environmental pollution. Most of the advanced devices are driven by electrical energy which indirectly results in harmful gas emission. Renewable energy-based advanced technology can be focused on developing countries as such sources offer a clean solution to environmental pollution problems.

Many of the advanced technologies have already proved an effective way of food preservation technique, but it does not guarantee the effectiveness at the same extent in developing countries. Therefore, not every modern technology is equally beneficial for developing countries. Comprehensive feasibility analysis would figure out the adaptability of a particularly advanced technology in specific developing countries.

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Chapter 10
Conclusion

Abstract The quantity of this highly valuable bounty is not uniformly distributed across the globe. Similar to having low per capita income and low urbanization growth, developing countries produce a relatively lower amount of food than developed countries do.The wastage of food causes not only scarcity of food but also adverse environmental and economic effects.There is a wide range of food preservation techniques prevailing across the globe nowadays. Individual techniques put importance on one or more than one of the key factors of food waste including microbial proliferation, enzymatic reaction, chemical reaction, as well as physical damage. Consequently, the required process conditions vary significantly through the preservation techniques. Prevention of microorganism growth is the main focus of many food prevention techniques including chilling and storing in favorable conditions. Many mistakes occur over the course of food preservation in developing countries. The mistakes affect the effectiveness of food preservation techniques negatively. Most of the mistakes are associated with lack of attention, guideline, as well as knowledge relating to food preservation system. Proper interventions must be taken into account in order to overcome the challenges and mistakes that take place during food preservation techniques. No single solution can eliminate the complexities of the challenges due to the diverse nature of the individual solutions.

Safe food is indispensable for humans. The quantity of this highly valuable bounty is not uniformly distributed across the globe. Similar to having low per capita income and low urbanization growth, developing countries produce a relatively lower amount of food than developed countries do. People in developing countries encounter acute hunger on a daily basis. On the other hand, significant loss of food takes place throughout the world. However, the prime causes of food waste vary through countries. A significant amount of food is being wasted at the consumer level in developed countries. On the other hand, postharvest loss accounts for the maximum wastage of food in developing countries.

Food is being wasted almost in every stage of food supply chain including harvesting, postharvesting, processing, and distribution as well as in consumer level.

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Reduction of wastage can be possible upon facilitating different initiatives. The wastage of food causes not only scarcity of food but also adverse environmental and economic effects. Therefore, interventions for preventing food waste must be put forward to overcome the hunger problem in developing countries.

From early history, humans felt the necessity of food storage and preservation. Human's inquisitive mind has innovated and discovered different food preservation systems throughout history. Most of the preservation techniques practiced by the early humans were based on daily experiences. Utilization of natural energy including solar and biomass, natural phenomena such as evaporation cooling, and spontaneous reactions like fermentation are some of the common features of these food preservation techniques. Many traditional food preservation techniques in developing countries still follow these approaches extensively. However, a wide variation prevails in each preservation technique in different regions of the globe.

There is a wide range of food preservation techniques prevailing across the globe nowadays. Individual techniques put importance on one or more than one of the key factors of food waste including microbial proliferation, enzymatic reaction, chemical reaction, as well as physical damage. Consequently, the required process conditions vary significantly through the preservation techniques. Prevention of microorganism growth is the main focus of many food prevention techniques including chilling and storing in favorable conditions. Temperature beyond the tolerance level of microorganism is maintained in these processes, whereas certain processes like cooking absolutely kill the microorganisms. Moisture removal is associated with a number of food preservation techniques including drying and smoking. In these processes, removal of water is done to such an extent that microorganism would be deprived of the required amount of water.

Moreover, prevention of chemical reaction is achieved through antioxidation process packaging. Different types of packaging techniques are practiced across the globe. Similar to chemical reaction prevention, inactivation of enzymatic reaction has taken place through some food preservation techniques such as blanching. Apart from these, there are some preservation techniques that encompass a set of these interventions during the course of the process.

The main purpose of food preservation is to save food from being wasted. Maintaining a fresh quality of preserved food does not get proper attention in developing countries, although many advantages such as low initial and maintenance cost and ease of operation and maintenance can be measured with local materials which are embedded in traditional food preservation techniques. Moreover, energy efficiency and processing time of the traditional preservation are not at a satisfactory level in most of the cases. Overall quality including shelf life can be improved to an appreciable extent. In order to improve energy efficiency, processing time, as well as quality attributes, mistakes and challenges associated with traditional food preservation must be addressed properly. On the other hand, improper preservation may hinder the food safety in the long run.

Many a time, improper preservation practices result in harmful effects on foods. In those cases, the preserved food is not only consequential but also dangerous for human. Contamination can be accessed through different pathways including biological, chemical, as well as physical ones. Improper process conditions, processing environment, wrong ingredient, and improper balance of processing components may cause mild to severe contamination in food materials over the time of preservation process. Out of the contaminations, excess chemical preservation and proliferation of microorganisms lead to severe negative health consequences. Proper hygiene practices, leaving harmful preservatives, and maintaining required preservation conditions would ensure the safe quality of preserved foods. On top of these, exercising basic ethics and moral duties can pave the way out from the contamination problems from the whole food chain.

Many mistakes occur over the course of food preservation in developing countries. The mistakes affect the effectiveness of food preservation techniques negatively. Most of the mistakes are associated with lack of attention, guideline, as well as knowledge relating to food preservation system. Although numerous mistakes take place during preservation techniques, avoiding the key mistakes would lead to eliminating many other mistakes.

Apart from avoidable mistakes, many challenges are encountered on a regular basis in developing countries. Diverse factors contribute to the overall challenges in food preservation systems. Lack of facilities, incorporation of technology, technical support, and necessary knowledge are the key factors that severely reduce the performance system. Each of the mentioned challenging factors results in low efficient preservation techniques as well as low quality of food.

Proper interventions must be taken into account in order to overcome the challenges and mistakes that take place during food preservation techniques. No single solution can eliminate the complexities of the challenges due to the diverse nature of the individual solutions. From the basic understanding of the science behind preservation techniques to research on complexity in food preservation, multiple initiatives need to be facilitated on an urgent basis. Therefore, a set of initiatives from all stakeholders is required to overcome food preservation-related challenges.

With the advancement of technology and better understanding, food preservation techniques are being changed day by day. Incorporation of feasible innovative technique can solve the challenges and enhance the overall performance of food preservation technology in developing countries. Although modern techniques offer enormous advantages, prior viability analysis must be conducted prior to incorporation in developing countries instead of traditional ones. Different constraints such as financial, technological, and environmental need to be considered preceding changing and modifying traditional food preservation techniques. Therefore, the optimization of advanced technology must be analyzed before implementing modern technology in food preservation in developing countries.

Index

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