Food Processing Waste Management

Treatment and Utilization Technologies

Food Processing Waste Management

Treatment and Utilization Technologies

Editors:

Dr. V.K. JOSHI
Professor & Head
Department of Food Science and Technology
Dr YSP University of Horticulture and Forestry
Nauni, Solan-173 230, Himchal Pradesh (INDIA)

&

Dr. S.K. SHARMA
GB Pant University of Agriculture and Technology
Hill Campus, Ranichauri, Distt. Tehri-Garhwal
Uttrakhand-249 199 (INDIA)

2021

New India Publishing Agency
Pitam Pura, New Delhi-110 088

Published by
Sumit Pal Jain *for*
New India Publishing Agency
101, Vikas Surya Plaza, CU Block, L.S.C. Mkt.,
Pitam Pura, New Delhi- 110 088, (India)
Phone: 011-27341717, Fax: 011-27341616
Mobile : 09717133558
E-mail: newindiapublishingagency@gmail.com
Web: www.bookfactoryindia.com

ISBN : 978-93-80235-59-2 E-ISBN : 978-93-89992-37-3

Typeset at: Harminder *for* Laxmi Art Creations # 98114 82328
Printed at: Jai Bharat Printing Press, Delhi
Distributed by NIPA GENX Electronic Resources and Solutions Pvt. Ltd. New Delhi

Dedicated

to

the Science and Technology of

Food Waste Management

Preface

Food processing has been identified as a sunrise sector and going to come up in a big way in time to come. Indian Government has also encouraged establishment of home, cottage and small scale industries especially in rural areas. Food industry on one hand provides diversified processed foods to satisfy the human palate and on the other hand generates huge quantities of the waste rich in organic matter. In the last few decades, there has been a growing health consciousness and concern about environmental pollution which has led to the formation of various laws and regulations all over the world. Discharge of pollutants in excess of established standards into the environment is a punishable offense as per law in many countries. The present goal is to achieve zero discharge of pollutants into water. But achieving it is a formidable, if not impossible task for industries, municipalities and governments. The end-of-the-pipe waste treatment is highly costly and non-productive. Furthermore, we still spend money to clean up our rivers, lakes and groundwater. Naturally, these costs are passed on to the citizens in the form of higher taxes and prices for goods and services. The law says that if an industrial plant continues to discharge pollutants in excess of established standards, it will be fined heavily and possibly put out of business. Since the food industry is comprised of many small-to-medium sized plants, the economics of scale predicts that it is going to cost the smaller plant more to dispose or treat a unit of processing waste than a larger plant. These challenges are being met with development of technologies which moderate the costs of waste treatment and make productive use of wastes.

Technologies for reducing the costs of waste treatment and making productive use of wastes are being developed for the last many decades. The traditional approach to use waste water is its land application mostly in irrigation of crops. But, this may also invite long term implications if waste waters contain undesirable compounds. For increasing production efficiency, various food processing modifications have been made and are being devised to increase production efficiency, reduce water consumption, keep solid wastes out of the wastewater stream and in many cases conserve energy. Technological developments such as dry caustic peeling reduce water consumption, increase product yields and keep peel waste out of wastewater with the potential for by-product utilization. Dry or steam blanching not only reduces water consumption, but leaches fewer nutrients from the products and conserves energy. More examples are found in various chapters in this book.

By-product recovery from solid wastes is another approach for reducing pollution abatement costs. Most end-of-the-pipe waste treatments also offer food processors the potential for by-product recovery. The wastes from the fruit and vegetable processing industries can successfully be converted into pectin, starch, animal feed, bio-colours, alcohol, etc. The shrimp industry generates shell waste, which is a good source of protein and high in calcium and phosphorous and can be used in livestock feed formulations. Shellfish waste is a rich source of chitin yielding up to 35% of the compound on dry weight basis. Chitosan obtained by the deacetylation of chitin has many pharmacological applications (anticoagulant, artificial kidney membrane, sutures, immuno-stimulants and anti-tumour agent). Peptides in the fish hydrolysates have functional role particularly in the aquaculture industry. Gelatin prepared from collagen is useful during encapsulation of thermolabile pharmaceuticals and in coating of photographic paper. Several industrially important enzymes can also be recovered from fish wastes. Similarly, the meat industry also generates a huge quantity of wastes such as offals and digests from the slaughtered animals which could be profitably utilized for production of value added products like Meat-cum- Bone Meal (MBM), Tallow, Bone chips, Pet Foods and methane. The wastes generated from the dairy processing industry can be converted into protein isolates, and other fermentable media. The recent innovations in technologies such as treatment of waste water without using any energy source or electricity and chemicals may open avenues for the generation of biogas (methane), besides cleaning the waste water. The book describes many of such options being employed or developed with respect to different food industries. But none of these, individually, is a complete solution to the environmental pollution problem. Perhaps an integrated approach is needed.

It is also evident that money spent on research for the development of food processing waste management by both the government agencies, the private industry and research institutes have yielded excellent returns which have been reviewed extensively in the present manuscript.

This book is expected to stimulate and open a new insight into research and development in cereal and grain processing industry, oilseed processing industry, fruit and vegetable processing industry, food fermentation industry, meat, fish and animal processing industry, milk processing industry and hotel industry along with the concerns pertaining to the environment and pollution control. The book covers appropriately technologies for all the segments of food industry. It is intended to drive home the concept that the waste from processing industry is an asset rather than liability and encourage the industry to use the waste to the maximum possible level rather than simply treating the same by reduction of Biochemical Oxygen Demand (BOD) and ultimate discharging into the stream. Of course, the plant effluent treatment technology can't be ignored so as to meet the requirement of law. The book is a studded with a large number of examples of to illustrate this point to enable food processing plant personnel to solve their own pollution abatement problems, to act as a guide when dealing with consultants and other specialists. Nevertheless, the book in itself cannot solve all the problems of each and every individual food plant; that can be done only by considering the individual requirements of the plant.

Finally, the key to success may lie with a new breed of waste managers – specialists who understand food science and engineering and who can look for ways and means of improving food processing to reduce pollution and finally who can develop by-products from the waste recovered. This Waste Manager should be responsible for waste management, well conversant with antipollution regulations, should also understand the concepts underlying the costs and financing pollution abatement. Rather the time has come when along with Plant Managers, Production Managers and Quality Control Managers; we may also have to appoint Wastes Managers in the food processing industries that are specialists in waste management

The chapters in the book have been contributed by the well known experts in the field. We acknowledge with sincere thanks the efforts of the authors of different chapters along with the information on various topics obtained from printed literature and websites that were consulted during the preparation of this manuscript. All the chapters have been illustrated by figures, tables and plates to make it more readable and interesting. Since the waste management has now become an integral component of food processing of all the PG course curricula in food science and technology, the manuscript would be of paramount importance to the students and teachers. It is expected that the manuscript would be welcomed by all those who have interest in the subject. However, constructive criticism and the suggestions are invited from the alert readers for future improvement of the same.

V.K.Joshi
S.K.Sharma

List of Contributors

1. **AS Bawa**, Defense Food Research Laboratory, Mysore-570011, Karnataka, India.

2. **AK Verma**, Department of Postharvest Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh-173230, India.

3. **Anil Gupta**, Department of Postharvest Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh-173230, India.

4. **BB Borse**, Department of Plantation Products Spices & Flavour Technology, Central Food Technological Research Institute, Mysore-570020, India.

5. **BA Shamasundar**, Department of Fish Processing Technology, Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar, College of Fisheries, Mangalore-575002, India.

6. **BK Wadhwa**, Dairy Chemistry Division, National Dairy Research Institute, Karnal, Haryana, India.

7. **C Joshi**, Himachal Pradesh Pollution Control Board, Baddi, Distt Solan, Himachal Pradesh, India.

8. **Chandralekha Sharma**, GB Pant University of Agriculture and Technology, Hill Campus Ranichauri, Distt Tehri-Garhwal, Uttarakhand-249199, India.

9. **Dev Raj**, Department of Postharvest Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India.

10. **GS Sharma**, Dairy Chemistry Division, National Dairy Research Institute, Karnal-132001, Haryana, India.

11. **HB Sowbhagya**, Department of Plantation Products Spices & Flavour Technology, Central Food Technological Research Institute, Mysore-570020, Karnataka, India.

12. **J Pura Naik**, Department of Plantation Products Spices & Flavour Technology, Central Food Technological Research Institute, Mysore-570020, Karnataka, India.

13. **K Radhakrishna**, Deptt of Freeze Drying and Animal Production Technology, Defense Food Research lab, Mysore-570011.

14. **MC Pandey**, Deptt of Freeze Drying and Animal Production Technology, Defense Food Research lab, Mysore-570011.

15. **M Madhva Naidu**, Department of Plantation Products Spices & Flavour Technology, Central Food Technological Research Institute, Mysore-570020, Karnataka, India.

16. **MV Chandra**, Department of Fish Processing Technology, Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar, College of Fisheries, Mangalore-575002, India.

17. **NS Thakur**, Department of Postharvest Technology, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India.

18. **Pushpa Singh**, Organic Chemistry Laboratory, Division of Plant Physiology and Biochemistry, Indian Institute of Sugarcane Research, Lucknow-226002, Uttar Pradesh, India.

19. **Rakesh Sharma**, Department of Postharvest Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India.

20. **RC Sati**, Department of Horticulture, GB Pant University of Agriculture and Technology, Hill Campus Ranichauri, Distt Tehri-Garhwal, Uttarakhand-249199, India.

21. **RK Bajaj**, Dairy Chemistry Division, National Dairy Research Institute, Karnal-132001, Haryana, India.

22. **S Arora**, Dairy Chemistry Division, National Dairy Research Institute, Karnal-132001, Haryana, India.

23. **S Slathia**, Department of Postharvest Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh-173230, India.

24. **Shachi Shah**, Department of Biological Sciences, GB Pant University of Agriculture and Technology, Hill Campus Ranichauri, Distt Tehri-Garhwal, Uttarakhand-249199, India.

25. **Shashibala Juyal**, Department of Horticulture, GB Pant University of Agriculture and Technology, Hill Campus Ranichauri, Distt Tehri-Garhwal, Uttarakhand-249199, India.

26. **SK Sharma**, Department of Horticulture, GB Pant University of Agriculture and Technology, Hill Campus Ranichauri, Distt Tehri-Garhwal, Uttarakhand-249199, India.
27. **VB Sashikala**, Deptt of Grain Science and Technology, CFTRI Mysore, Karnataka, India.
28. **VM Pratape**, Deptt of Grain Science and Technology, CFTRI Mysore, Karnataka, India.
29. **V Sharma**, Dairy Chemistry Division, National Dairy Research Institute, Karnal-132001, Haryana, India.
30. **V Venket Ramnan**, Evolution Academy, Delhi-110009, India.
31. **Vandana Sohlia**, Deptt of Freeze Drying and Animal Production Technology, Defense Food Research lab, Mysore-570011.
32. **Vasudeva Singh**, Deptt of Grain Science and Technology, CFTRI Mysore, India.
33. **VK Joshi**, Department of Postharvest Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh-173230, India.
34. **YP Thapliyal**, Department of Hotel Management, Alpine Institute of Management and Technology, Dehradun, India.

Contents

Preface v
List of Contributions vii

1. Food Processing Industrial Waste Present Scenario 1
   VK Joshi and SK Sharma

2. Impact of Food Industrial Waste on Environment 31
   Shachi Shah, V Venkat Ramanan and SK Sharma

3. Grain Processing Waste Management 53
   VM Pratape, Vasudeva Singh and VB Sashikala

4. Fruit and Vegetable Processing Waste Management 73
   NS Thakur, VK Joshi, and S Slathia

5. Milk and Dairy Waste Management 97
   S Arora, RK Bajaj, V Sharma, BK Wadhwa and GS Sharma

6. Meat Processing Waste Management 125
   Vandana Sohlia, MC Pandey, K Radhakrishna, AS Bawa

7. Fish Processing Waste Management 161
   MV Chandra and BA Shamasundar

8. Spices and Condiments Industrial Waste Management 195
J Pura Naik, HB Sowbhagya, M Madhava Naidu and BB Borse

9. Sugar and Jaggery Industrial Waste Management 229
Pushpa Singh

10. Fruit Kernel and Oilseed Processing Waste Management 257
SK Sharma, Anil Gupta, Rakesh Sharma, AK Verma, RC Sati and Shashi Bala Juyal

11. Utilization of Waste from Food Fermentation Industry 295
VK Joshi, Dev Raj and Chetan Joshi

12. Food Processing Waste Treatment Technology 357
C Joshi

13. Hospitality Industry Waste Management 413
YP Thapliyal and Chandralekha Sharma

14. Emerging Waste Management Technologies — Nanotechnology 427
Shachi Shah, V Venkat Ramanan and SK Sharma

Index 439

1

Food Processing Industrial Waste — Present Scenario

VK Joshi & SK Sharma

1.1 Introduction

Due to the ever increasing world population, the demand for food would also increase. India is one of the largest food producer countries of the world (first in milk production, second largest in fruit and vegetable production and third largest in grains production). It is the seventh-largest country in the world, with a total land area of 3,287,263 square kilometres. India has varied climates of snow covered Himalayas, desserts, oceans, fertile plains and areas receiving the highest rainfall in the world. Name any food item; it can be grown in one or the other part of the country. All these make the production of various types of foods of plant (fruits, vegetables, cereals, pulses, oilseeds, spices etc) as well as animal origin (fish, meat, milk etc.) possible in the country. The annual production of cereals, fruits and vegetables is 260, 57 and 77 million tonnes respectively, besides this, the production of cow and buffalo milk is about 102.1 million tonnes and that of sugarcane and spices are 355.52 and 1.1 million tonnes respectively [15].

Table 1 shows that the production of various food items has increased many folds during the last five decades. On one hand, we feel proud as we produce one of the largest quantities of foods in the world and there has been an enormous rise in the production of various foods in India during the last five decades, on the other hand we should be very much worried being a leading country as far as the wastage of food in the world is concerned. The postharvest losses are huge and only meagre quantity (2%) of the food is processed. Sharma [41] very rightly said that when we do not agree to throw away Rs 4000/- per month out of a salary of Rs 10,000/- per month then why do we accept 40% postproduction losses of food in the country. This would require immediate necessary action to save a major portion of the food that has already been produced.

The 'Food Processing Industry' in India is one of the largest in terms of production, consumption, export and growth prospects and has been recognized as a sunrise sector. A number of fiscal reliefs and incentives, to encourage commercialization and increase in value addition of agricultural produce, minimizing pre and postharvest wastage, generating employment and export growth indicate that the Indian government has given a high priority to the Food Processing in India. But, presently due to inadequate infrastructural facilities and poor postharvest management, the post production losses in food commodities in India during storage, handling and milling/processing have been assessed to the tune of Rs. 75,000-1,00,000 crore per annum [8].

The various sectors of food processing industries are engaged in the production of different types of processed products and generating various types of wastes. These wastes, whether solid or liquid, on one hand are a direct loss to the producer or manufacturer and on the other hand create environmental pollution, if not disposed off properly. Therefore, the processors would always like to minimize these wastes. The generation of wastes not only cause economic losses but would also require additional cost for their management and disposal. As a matter of fact, it is often estimated that proper use of efficient machinery and careful handling during various operations can lead to more than 50% reduction in losses.

In general, the wastes from the food processing industries are either not utilized or primarily utilized as animal feed, fertilizer and in preparation of by-products on a limited extent. Many of the wastes such as cutting and shreds from the fruit and vegetable processing industry, rice stem material from the rice grain industry can be used as an animal feed. Fruit and vegetables wastes can also be used for extraction of starch, pectin, natural colouring matter, fat, essential oils etc [31]. Wheat and maize bran alongwith palm kernel are used for the production of feed for chickens [35]. A number of non-edible by - products can also be manufactured from the meat processing industry i.e. glue, leather goods, ointments, industrial oils, lubricants, paper boxes, plaster binders etc. Important by-products arising from the dairy industry and milk processing industry include butter milk, ghee residues, whey, casein etc. Various oils and oleoresins having enormous pharmaceutical properties, can be obtained from the spice processing industry.

Table 1: Production statistics of various commodities over the last five decades

Crop	1961		2007		Increase in production %
	Production (tonnes)	Area (ha)	Production (tonnes)	Area (ha)	
Fruits excluding melons	13372500	1549170	57467600	5421875	429.74
Vegetables and melons	18468500	2779350	77243300	5904800	418.24
Oil crops primary	3122730	23669000	12019486	39193000	384.90
Tree nuts	97000	214000	653000	884800	673.20
Oil cakes	4419819	23183000	23451556	38333000	530.60
Cereals	87376496	92239016	260480000	99472000	298.11
Coarse grains	22885000	44618016	40110000	27667000	175.27
Buffalo Milk	-	-	59210000	37200000 (Producing animals)	-
Cow milk	-	-	42890000	38000000 (Producing animals)	-
Sugarcane	110001008	2413000	355520000	4900000	323.20
Spices	163000	-	1100000	600000	674.85

Oil crops primary include castor oil, coconut, ground nut, linseed, rape seed, safflower, seed cotton, sesame, soybean, sunflower

Tree nuts include walnut and cashew nut only

Oil cakes include coconut, ground nut, linseed, rape seed, safflower, seed cotton, sesame, soybean, sunflower

Cereals include barley, maize, millet, rice, sorghum, wheat

Coarse grains include barley, maize, millet, sorghum

Source: Ref [15]

But, it is a paradox that despite of the huge potential of food processing industrial waste management technologies in reduction of economic losses and generation of additional income, much emphasis and interest has not been shown either by the industry or the government in this area of science. Though people talk much about reduction of postharvest losses, the waste management industry has not been prioritized and is still in infancy in India.

Various chapters in this book covering cereals and grains, fruits and vegetables, oilseeds, spices and condiments, milk, meat, fish, sugarcane, fermentation, environment etc., would address a number of issues pertaining to food processing industrial wastes and technologies for waste management in the respective industries.

1.2 Important Sectors of the Food Processing Industry

The food processing industry can be divided into the following sub-sectors, producing various kinds of processed products and generating different wastes;

- Cereal and grain processing
- Fruit and vegetable processing
- Fish processing
- Milk processing
- Meat & poultry processing
- Packaged/Convenience foods
- Alcoholic beverages and Soft drinks
- Spices and condiments Industry
- Sugar and Jaggery industry
- Fermented food industry
- Nuts and oilseed processing

The above sectors of the food processing industry are involved in processing of specific foods and generate specific types of wastes. eg peel, skin, seed, pulp etc are generated from fruit and vegetable processing industry while, hair, hide, blood etc are generated from meat processing industry. Therefore, the waste management strategies of the various sectors would also differ from one another and need research and innovations specific to the industry. But, some common types of wastes are also generated in almost all sectors of the food processing industry viz., wash waters, equipment cleaning, spills etc. In such cases, common strategies or similar strategies with slight modifications, may be adopted for the waste management. Certainly, this needs immediate attention of everybody, including government, industry, organisations as well as individuals, otherwise, we would be lost wasting our resources for increasing food production and generating food wastes, ultimately causing pollution. Generation and management of wastes from different sectors of food processing industry alongwith their impact on environment and pollution, and control strategies thereof, shall be discussed in detail in the following chapters.

1.3 Waste Generation

1.3.1 Waste

Waste is any unwanted, undesirable, discarded or intended to be discarded material left-over after the completion of a certain process (food product manufacturing process in this book). *Waste* is also synonymously referred to as rubbish, trash, garbage, or junk. There are many wastes types, i.e. municipal solid waste, commercial waste, hazardous waste, food processing wastes etc. The European Union defines *waste* as an object- the holder discards, intends to discard or is required to discard is waste under the Waste Framework Directive (European Directive 75/442/EC as amended). *Once a substance or object has become waste, it will remain waste until it has been fully recovered and no longer poses a potential threat to the environment or to human health* [5]. This definition was amended by the Waste Management Licensing Regulations, 1994, defining waste as: *"any substance or object which the producer or the person in possession of it, discards or intends or is required to discard but with exception of anything excluded from the scope of the Waste Directive"* [12].

Having defined the material was waste, various pieces of legislation including the Environmental Protection Act 1990, the Controlled Waste Regulations 1992 and the Waste Management Licensing Regulations 1994, seek to further define the types of wastes as they are legally defined by the processes or premises from which they are produced [12].

- *Controlled waste* encompasses household, industrial and commercial waste.
- *Household waste* is that which arises from dwellings of various types including houses, caravans, houseboats, campsites, prisons and wastes from schools, colleges and universities.
- *Commercial waste* comes from premises used wholly or mainly for trade, business, sport, recreation or entertainment; excludes household and industrial waste.
- *Industrial waste* is waste from a factory or industrial process; it excludes wastes from mines and quarries, and agricultural wastes.

- *Agricultural wastes* (non-natural wastes) and mining and quarrying recently came into the same controlled waste regime.
- Some controlled wastes are further classified and subject to further regulation because of the nature of the waste and the need to handle them differently.
- *Clinical waste* comes from hospitals, nursing homes, dentists, surgeries etc. and can also include wastes from the household.
- *Hazardous/special wastes* are hazardous for a variety of reasons including toxicity, explosiveness, radio activity etc. They also must be handled and dealt with differently to other wastes.

The generation and type of wastes have also changed with human development e.g. paper, plastics, nuclear wastes during different stages of development and innovations in science and human existence.

Subjectively, the discards or wastes of one individual or organization may have great value to others that is why it is said that "*wastes are a valuable resources*". As a nation, Americans generate more waste than any other nation in the world with 4.5 pounds of municipal solid waste (MSW) per person per day, 55 percent of which is contributed as residential garbage. The remaining 45 per cent of waste in the U.S.'s 'waste stream' comes from manufacturing, retailing, and commercial trade in the U.S. economy [6]. In food processing industry, wastes may include poinace, whey, bones, skin and peels etc.

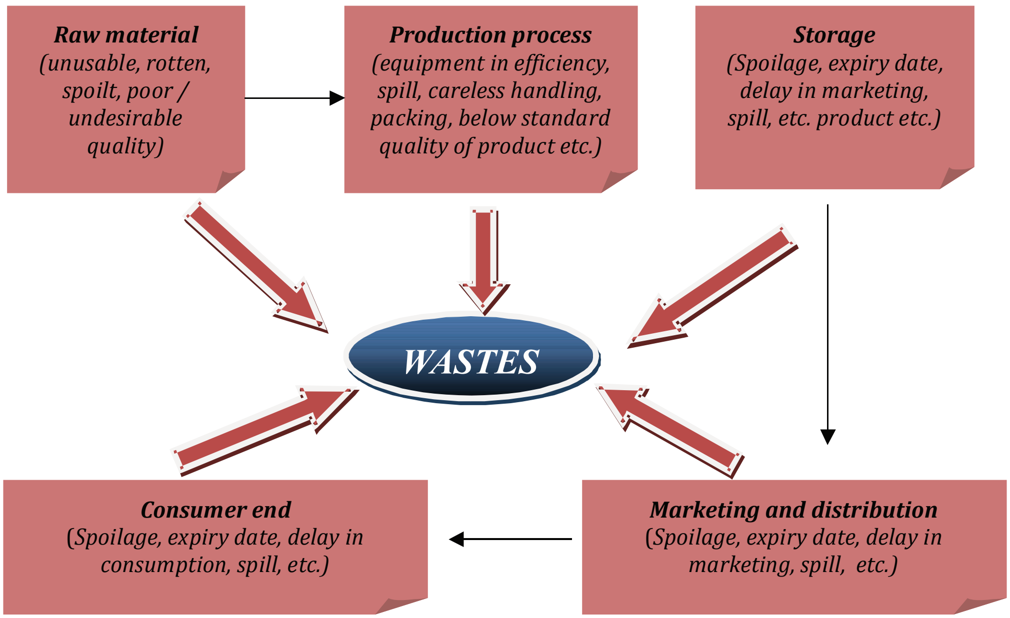

Fig. 1: Sources of wastes in food processing industry

Fig 1 explains the sources of waste generation in the food processing industry. The generation of wastes actually starts from the raw material itself. If the raw material is of improper quality and is unusable (bitter taste, improper colour, flavour etc.) and if there is a delay in processing the raw material (especially in case of fruits, vegetables, milk, meat, fish etc.), the raw material itself may be spoilt and has to be discarded as waste. In case of production or manufacturing process, the wastes may be generated as equipment inefficiency, spillage, improper handling etc. Even if the product after completion of production process does not match the company standards it has to be discarded as waste. If the product expires in storage due to untimely sale, and distribution, it may also have to be discarded as waste. Similarly, a remarkable quantity of products if not packed and handled properly can become waste during the marketing, transportation and distribution. Some quantity of product is also waste at consumers end, due to delay in consumption, improper use etc. Measuring of the losses and wastes at consumers end is very difficult or practically impossible due to their large number and existence over a large area.

1.3.2 Composition of wastes

In general, wastes are composed of organic material, glass, metal, paper, plastic, wood etc [1]. Table 2(a&b) would give the examples of the composition of waste material produced and released into environment. Some of these wastes are recyclable i.e. they can be reformed into different shapes and sizes after melting and reformation process, but others are non-recyclable. Organic material is biodegradable, whereas glass, metal, plastics are generally not. Nuclear wastes commonly generated during irradiation in food industry are highly harmful to human beings as well as other forms of life on earth therefore, should be handled and disposed off very carefully.

1.3.3 Pollution problems

According to the Central Pollution Control Board, the pollution problems in agro- based industry are caused mainly by the wastewater and solid wastes generated during product manufacture. Air pollution problems are caused by food processing industries during the material handling, combustion processes (heating, boiling etc.). Various types of pollution problems as given below have been discussed [2].

a. *Water Pollution*: Concomitant with water consumption, agro- based industries generate large volumes of effluents. The agro-based industry is the second largest generator of pollution due to organic matters in the country, standing next only to the domestic sewage. However, most of the effluents are bio-degradable and commonly non- toxic, therefore they may easily be treated biologically.

Table 2a: Waste material components

Component	Examples
Water	Used in food and most other industries and released into environment as effluent.
Organic material	Leaves, peel, scraps, seed, pulp, hair, hide, spoiled food, plant tissues, food wastes
Glass pieces	Windows*, vehicles, glass bottles*
Human and animal waste	Urine, feces
Metals	Cans*, high tech waste*, scrap metals*, cooking appliances*, equipments, building materials*
Paper	Newspaper*, office paper*, packing materials, cardboard*
Plastic	Beverage containers*, high tech waste*, primary, secondary and tertiary packing materials
Wood	Furniture, building materials, pallets*
Nuclear wastes	Irradiation treatment

* denotes recyclable wastes.

Table 2b: Composition of some food wastes

Constituents	Whey	Citrus molasses	Palm oil mill effluent	Fresh apple pomace	Dried apple pomace
Dry matter / Total solids (%)	5.8-6.8	71	4	10-33.6	87.5-89
Moisture (%)	93.2-94.2	29	96	66.4-90	11-12.5
Carbohydrates (%)	-	-	-	9.5-22	-
Glucose (%)	-	-	-	-	17-22.7
Fructose (%)	-	-	-	-	23.6-40
Reducing sugar (%)	-	23.5	-	-	-
Sucrose (%)	-	-	-	-	1.8-5
Total sugars (%)	-	-	-	-	48.1-62
Lactose (%)	4.2-4.7	-	-	-	-
Pectin (%)	-	1.0	-	1.5-2.5	15.0-18.0
Crude fibres (%)	-			10.5-43	15.3-20.0
Proteins (% N x 6.25)	-	4.1	-	1.03-1.82	4.45-5.67
Albumin (%)	0.8-1.0	-	-	-	-
Fat (%)	0.2-0.4			0.82-1.43	3.75-4.65
Biotin (μg/kg DM)	325-599				

Contd...

Table 2b. Contd...

pH	-	5.0	3.5-4.5	3.5-4.1	-
BOD (mg / L)	-	-	25,000	-	-
COD (mg / L)	-	-	60,000	-	-
Suspended solids (mg / L)	-	-	19,000	-	-
Total N (mg / L)	-	-	770	-	-
Oil and grease (mg / L)	-	-	8,000	-	-
Ash (%)	-	0.7	-	-	-
P (ppm)	-	600	110-156	-	-
K (ppm)	-	11000	1420-2165	-	-
Mg (ppm)	-	1000	210-350	-	-
Ca (ppm)	-	8000	230-345	-	-
Na (ppm)	-	3000	25-63	-	-
Mn (ppm)	-	20	1.7-3.8	-	-
Iron (ppm)	9.16	400	62-130	-	-
Zinc (ppm)	32.5		1.0-2.1	-	-
Copper (ppm)	0.32	30	1.0-1.05	-	-
Cobalt (mg/kg DM)	0.052	-	-	-	-
Molybdenum (mg/kg DM)	0.573	-	-	-	-
Niacin (ppm)	-	35	-	-	-
Riboflavin (ppm)	-	11.0	-	-	-

Source: Ref [43, 36,13, 28, 39, 42]

b. *Air Pollution*: Steam and heat are used in large quantities in agro-based industry during, heating, peeling, sterilization, cooking, blanching etc. Particulate emissions occur during burning of fuels and handling of raw materials before processing and waste utilization. In agro-based industries, mal-odorous conditions are due to poor handling and the management of wastes generated.

c. *Solid Wastes*: Sizeable quantities of hulls, shells, stalks, steeps, peels, hair, flesh etc. are produced during the processing of raw materials and refining the products. Frequently, these materials can be utilised as animal feed or manure or further refined to produce useful and marketable products.

1.3.4 Classification of wastes

According to their nature of decomposition wastes can be categorized into two groups i.e. (a) Biodegradable wastes and (b) Non-biodegradable wastes.

a. *Biodegradable waste*: The wastes are generally of biological origin that can be composted or anaerobically digested by microorganisms to produce soil improvers, or renewable fuels. If the disposal of biodegradable waste is not controlled it can cause a number of severe problems including release of greenhouse gases and impact upon human health via encouragement of pathogenic microorganisms.

b. *Non-biodegradable wastes*: The wastes which cannot be degraded by microorganisms e.g. metal, some plastics etc.

According to their phase, wastes can be categorized into following groups;

a. *Solid*: Sizeable quantities of hulls, shells, stalks, leaves, seeds, skin, hair, steeps, spills etc. are produced in various food processing industries

b. *Liquid*: wash water, blood etc.

c. *Gas / waste heat*: volatiles, aroma compounds etc.

Wastes released into the environment as phase b and c above are referred to as *Emissions*.

According to their measurement ability, wastes can be categorized into two categories:

a. *Tangible*: quantity of water, solids etc.

b. *Intangible* : wasted time or wasted opportunities etc.

According to the recyclability, wastes can be categorized into two categories:

a. Recyclable e.g. plastic bottles, metals, glass, paper etc.
b. Non-recyclable: eg soluble solids

There are different types of waste or waste streams which are produced by a variety of processes. Each waste type has different methods of associated waste management [3].

Agricultural sector forms a basis for providing raw material to about 45% of the medium and large scale industries in India i.e. almost one-half of our industries are agro-based [2]. Most of the major agro-based industries are located in the States of Andhra Pradesh, Gujarat, Karnataka,) Madhya Pradesh, Maharashtra, Tamil Nadu and Uttar Pradesh. The state wise number of licenced food processing industries in India is presented in Table 3. The estimated quantity of wastes generated and waste streams of food industry are given in Tables 4 and 5, respectively.

Table 3 : Statistics of some agro-based industries in India

Type of Industry	Total No.	Annual Processing of Units	States where located /Production Capacity
Dairy	96	5.5 x 10.6^6 Kilolitre	Uttar Pradesh, Maharashtra, Gujarat, Tamil Nadu, Rajasthan
Edible Oils & Vanaspati	725	4.5 x 10^6 tonne	Maharashtra, Andhra Pradesdh, Gujarat, Madhya Pradesh, Uttar Pradesh
Food & Fruit Processing	204	-	Maharashtra, Tamil Nadu, Andhra Pradesdh, Karnataka, West Bengal
Starch (Maize Products)	11	0.2 X 10^6 tonne	Gujarat, Andhra Pradesdh, Uttar Pradesh, Haryana
Sugar	400	10 x 10^6 tonne	Maharashtra, Uttar Pradesh, Andhra Pradesdh, Gujarat, Karnataka, Tamil Nadu
Fermentation	225	2 X 10^6 Kilolitre	Uttar Pradesh, Maharashtra, Andhra Pradesdh, Madhya Pradesh, Karnataka, Tamil Nadu

Source: Ref. [2]

Table 4: Estimated quantity of waste generated in India

Waste	Quantity
Municipal solid waste	27.4 million tones/year
Municipal liquid waste (121 class I and II cities)	12145 million litres/day
Distillery (243 nos)	8057 kilo litres/day
Pressmud	9 million tonnes/year
Food and fruit processing waste	4.5 million tonnes/year
Dairy industry waste (COD level 2 kg/m^3)	50–60 million litres/day
Paper and pulp industry waste (300 mills)	1600 m^3 waste water/day
Tannery (2000 Nos.)	52500 m^3 waste water/day

Source: Ref. [9]

Table 5. Waste streams in food processing sectors

Industry subsector	Waste streams
Dairy products	(i) Spills
	(ii) Production residuals
	(iii) Off-specification and outdated products
	(iv) Cleaning or transport, production and other equipments
	(v) Truck wash water, tank wash/ rinse water
	(vi) Sanitizing chemicals
Fruit and Vegetable products	(i) Overflow, spillage from conveyers, packaging
	(ii) Rejects, peels, outdated material
	(iii) Conveying water, plume water, wash water, occluded solubles (sugars, acids, starch etc)
	(iv) Blanching water
Meat	(i) Blood and blood rinse
	(ii) Hides, hair
	(iii) Paunch manure
	(iv) Inedible fats
	(v) Rendering water
	(vi) Eviscerated parts
Poultry	(i) Blood and blood rinse
	(ii) Scalding water
	(iii) Feathers
	(iv) Eviscerated parts
	(v) Flume water
	(vi) Wash water

1.3.5 Water consumption

A huge quantity of water is used annually in different agro-based industries in the country. A major portion of the water used for cleaning and washing purposes is also released as emission into the environment, although the volumes of water consumed vary widely from plant-to-plant and from industry-to-industry. Variations between various industry segments for water use have been given in Table 6 [2].

Table 6: Water consumption, wastewater generation and organic pollution load in agro-based industries

Industry	Specific Water Consumption (Cubic meters)	Waste Water generation, Cubic Metre	Pollution load (in terms of Kg of BOD)
Dairy (Integrated) (per kilo litre of milk)	8.7	6.0	11.0
Edible Oils & Vanaspati (per tonne oil)	3.0	2.0	7.5
Fermentation (i) Brewery (per Kilo litre of beer)	11.5	9.5	24.0
(ii) Distillery (per kilo litre of alcohol)	130.0	90.0	600.0
(iii) Maltry (per tonne of grain)	8.5	3.5	2.0
Starch (Maize Products) (per tonne of maize)	8.0	5.5	44.0
Sugar (Per tonne of cane crushed)	2.0	0.4	0.5

• Figure are per unit of processing/production, Source: Ref. [2]

All food processing industries have common characteristics for waste water discharge. The major pollution parameters of wastewater of concern are pH, total suspended solids, biological oxygen demand (BOD), oil, grease, nitrogen and phosphorus (nutrients available for bacterial growth.) [25].

1.4 Nature of Wastes

There are different types of wastes generated from the food processing industries and these are generated during various unit operations in food processing. As depicted in Tables 7, 8 and 9 the quantity of wastes generated may be as high as 60-70 % of the raw material and the nature of these wastes may be peel, core, trimmings, fibre, hull, kernel, shreds, seeds, coarse solids, pulp, pomace, rind, wash water, syrup, alum (Fig. 2) etc. in the processing industries based on plant raw material while that from animal processing industries may be blood, bones, hair, fat, hide, residue concentrate, butter milk, whey, separated milk, dilution of whole milk etc. [37, 41].

Table 7: Wastes generated during various unit operations in food processing industry

Industry / Products	Unit operations	Nature of wastes
Canning	Trimming, cutting, blanching	Food/ fruit pieces, juice, water, syrup, brine etc.
Dairy products	Pasteurization, packing, filtration etc.	Butter milk, whey, separated milk, dilution of whole milk etc.
Brewed and distilled beverage industry	Washing, steeping, pressing, packing,	Condensate from evaporation, residue from distillation of alcohol, water,
Meat and poultry products	Slaughtering, washing,	Wash water, blood, bones, fat, residue concentrate
Yeast	Filtration	Residue
Pickles	Washing, cutting, trimming, preparation, packing	Brine, alum, turmeric, syrup, solid fruit and vegetables pieces
Coffee	Pulping, fermentation	Solids, water
Fish	Pressing, centrifugation, washing, evaporation	Water, residue
Rice	Washing, cooking, soaking,	Water, soild grains
Soft drinks	Washing, bottling, packing	Wash water, sugar syrup,
Bakery	Washing, greasing	Wash water, soilds

Table 8: Food processing waste utilization and manufacture of by-products

Crop	Waste (%)	Nature of Waste	By Products
Apple	20-30	Pomace	Juice, wine, vinegar, pectin, cattle feed etc.
Orange	50	Peel, Seeds, Pulp	Essential oils, pectin, cattle feed, peel candy etc
Lime	60	Peel, Seeds, Pulp	Essential oils, pectin, cattle feed, peel candy etc
Mango	40-60	Skin and Stone	Mango fat, bio colour
Mango Peels	12-15	Peel and pulp	Pectin, cattle feed, alcohol
Pulper waste	5-10	Fibre	Wine, vinegar, juice

Contd...

Table 8. Contd...

Kernels	15-20	Hull and Kernel	Fat, tannins, starch
Pineapple	30-60	Peel, Core, trimmings, shreds	Juice, wine, syrup, cattle feed, biogas
Tomato	20-30	Core, peel, seeds	Animal feed, seed oil and meal
Potato	-	Peel, Coarse solids	Animal feed, single cell proteins
Banana	20-30	Peel	Animal feed
Wild apricot	60-70	Pulp, stone, kernel	Beverages, oil, cosmetics, processed products
Tamarind	-	Seeds	Starch for textile industry
Aonla	-	Fruit, pulp	Ayurvedic drugs
Pea	60-65	Pod	Animal feed
Cucumber	-	Seeds	Maghaz
Grape	-	Stem, pomace	Cream of tartar, jelly, chutney
Guava	-	Cores, seeds, peels	Guava cheese
Passion fruit	-	Rind, seeds	Pectin, oil
Pear	-	Peel, core	Animal feed, perry, vinegar

Source: Ref [41]

Table 9: Average quantity of by-products made for every 100 MT sugarcane ground

By-products	Quantity
Raw sugar (98.8^o POL)	11.2
Surplus bagasse (49% moisture)	5.0
Molasses (89^o B)	27
Filter mud (80% moisture)	30
Furnace ash	0.3

Source: Ref [34]

1.5 Waste Minimization and Management

Environmental legislation has significantly contributed to the introduction of sustainable waste management practices throughout the World. The primary aim of waste legislation is the prevention of waste generation. Waste prevention refers to three types of practical actions, i.e., strict avoidance, reduction at source, and product re-use. However, waste prevention does not only include the reduction of absolute waste amounts but also avoidance

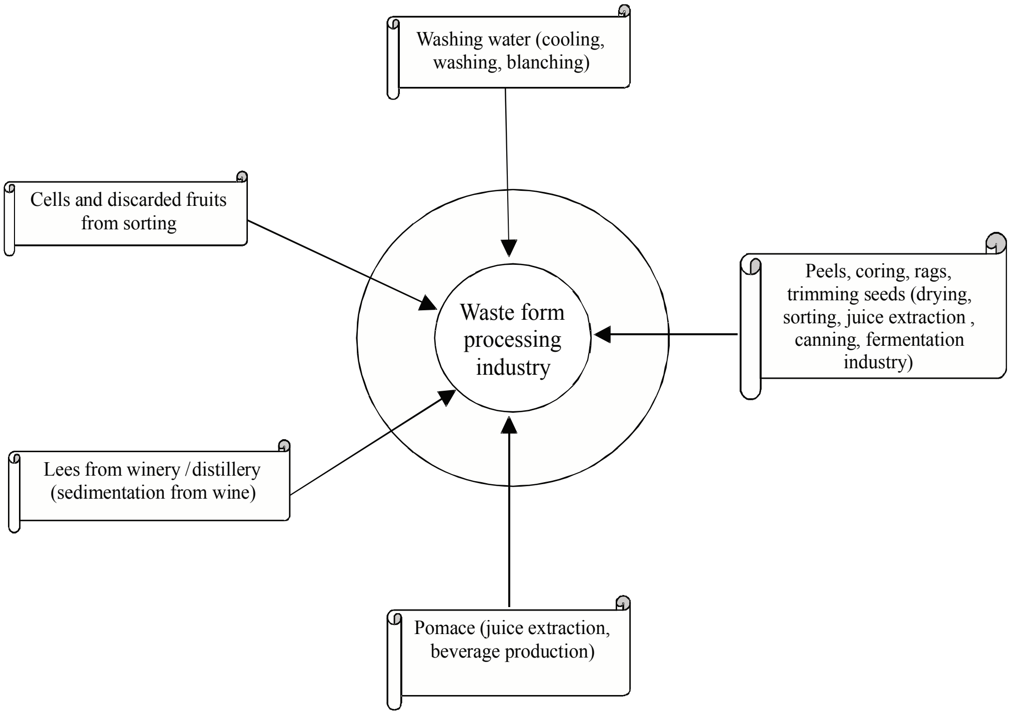

Fig 2 : Major sources of pollution load in fruit and vegetable processing industry [29]

of hazards and risks because safety is also of major concern. Considering the waste management options, at the top of the hierarchy stands waste minimization that includes [40]:

- Waste prevention i.e. reduction of waste by application of more efficient production technologies;
- Internal recycling of production waste;
- Source-oriented improvement of waste quality, e.g. substitution of hazardous substances;
- Re-use of products or parts of products, for the same or other purpose.

1.5.1 Management of wastes

The management of wastes of food processing industries is relatively easy because;

1. Waste (discarded materials) from one segment may be a by-product and can be used as raw material for other sub-sectors of the food processing industry. For example;

   a. Apple pomace obtained from the juice processing industry can be a raw material for pectin manufacturer
   b. Molasses from sugar mills are raw materials in distilleries
   c. Bagasse from sugar mills are raw materials in pulp and paper mills
   d. Citrus peel discard are raw material for essence manufacturing industry

2. By setting up of auxilliary units to process all the by-products as indicated above, there will be a better utilisation of all the materials (wastes and discards) resulting in greater benefit to the economy. It will eliminate import and transport of raw materials (for auxillary industry) from one place-to-another
3. A good by-product recovery process would reduce a remarkable proportion of the cost of waste treatment.
4. The availability of land for waste treatment as well as air pollution disposal is not a limitation because a large segment of the agro- industry is in rural areas.

Waste management refers to all the operations and activities done in order to reduce waste generation, reduce the bulk of generated waste and disposal of generated waste (Fig. 3). *Waste management* may also be defined as the deliberate and controlled collection, treatment and disposal of different wastes in order to reduce its negative impacts on environment and society.

Primarily the following steps can be taken in order to reduce wastes

a. *Prevent generation of waste*: Use efficient production technology, careful handling and transportation, and reduce the actual quantity of wastes generated.
b. *Waste minimization i.e. minimise the bulk of generated wastes*: This can be done by separation of wastes into various categories i.e. solid, liquid, gas or bio-degradable and non-biodegradable etc. so that their bulk is reduced.
c. *Use wastes for production of by-products, if possible*: Auxillary industries could be set up for the utilization of different types of wastes for the manufacture of by-products.
d. *Waste treatment*: This may involve recycling of wastes, bulk reduction etc. by various aerobic and anaerobic biological treatments.

e. *Waste disposal*: Dispose the leftover into the environment carefully so that it creates minimum of disturbance to the environment.

Prevent waste generation

⇓

Minimize wastes

⇓

Prepare by-products

⇓

Treat left-over of wastes

⇓

Dispose-off

Fig. 3 : Preferred order of operations in waste management

A. Waste Prevention

This is the first and foremost step in waste management process. We should try as much as possible to reduce the quantity of wastes actually generated by an industrial process. This can to a larger extent be achieved by;

i. Use of efficient equipment

ii. Careful handling, reducing spillage during production, packaging, transportation, storage etc.

iii. Timely utilization of raw material: Do not let the raw material i.e. fruits, vegetables, milk, meat etc., spoil before their conversion into finished products

iv. Timely marketing of finished products : Do not let the finished products spoil before marketing and use

v. Proper storage conditions for raw materials as well as finished products

B. Waste Minimisation

Environmental management in industries has so far been focused mainly on pollution control through 'end-of-pipe' treatment technologies, which is a curative approach for pollution problems. By adopting appropriate preventive measures, generation of wastes can be minimised. This will help in two ways; firstly, it will reduce the cost of treatment, and secondly, it will conserve a raw materials by way of reducing their wasteful usages [2]. According to the Central Pollution Control Board, the three golden principles of waste minimisation are:

1. What can be measured, can be managed
2. Nothing comes from nowhere {Cor.: Everything comes from somewhere)
3. Nothing goes away nowhere {Cor.: Everything goes somewhere)

The Central Pollution Control Board recommends adoption of the following practices for waste-minimisation in case of agro-based industries [2].

1. *Accounting and Balancing of Raw and Other Resources*: By proper record keeping of quantities of raw materials and other resources used for various unit operations and analysing the fate of all the throughputs, a check on the excess use of these resources can be made. This will also help in identifying the gaps in the stoichiometric and the actual requirements of the needed inputs and hence, the (in) efficiency of a particular unit operation/process.
2. *Characterization of process water and wastewater*: A careful survey of water usage and waste generation points in various processes and measurement of their quantities and characteristics will help identifying any possibility for the recycle of discarded waters, such as cooling water, condensate water etc. An excellent example for this case is the sugar industry. A lot of hot condensate water is generated in a sugar mill during the manufacturing processes which can be recycled as boiler feed and imbibitions water for the better extraction of juice from sugarcane.
3. *Segregation of Waste Streams*: It is better to segregate less or mildly polluted streams from highly polluted ones. For example, black liquor from the pulping process in a paper mill should be segregated for recovory of lignin, and then it could be mixed wIth other streams to make the combined waste easily amenable for further biological treatment.
4. *Combining the Compatible Waste Streams*: Characterization of various waste streams will help in identifying compatible streams. By combining such streams, cost of their treatment can be minimised. For example, acidic stream from the juicing section in a fruit processing industry can be combined with the alkaline streams from the other sections to neutralise both the streams and save cost on chemicals.

With the waste minimisation practices, generation of wastewaters from almost all the agro- based industries can be reduced to a large extent. There are some examples already existing in cases of sugar mills, where the wastewater generation has been reduced by more than 50% and the pollution load by over 70%.

a. Application of membrane processes for waste minimization

Membrane process involves the separation of water from the solids by passing the material under pressure through a membrane (Fig. 4) which permits only smaller particles to pass through it (the permeate). Bigger sized particles are retained on the top (the retentate). It uses the difference of particle size as the basis of separation [41]. Appropriately-used membrane separation can provide financial savings and conserve resources. Maximum benefits are obtained when one or both the output streams from the membrane system are recycled or re-used, thereby reducing process materials requirement and minimising waste disposal costs. Compared with conventional processing, membrane technology has many advantages. By implementing membranes, the separated substances are often recoverable in a chemically unchanged form and are therefore, easily re-used. Membrane separation units are compact and their modular construction means that they can be scaled up or down easily. State-of-the-art membrane technology methods offer the possibility to enhance food safety, and reduce the energy consumption and the environmental impact of food processing. Membrane separations are applied for concentration (removal of a diluting solvent such as water); purification (separation of contaminants) and fractionation (resolution into two or more component substances) [38].

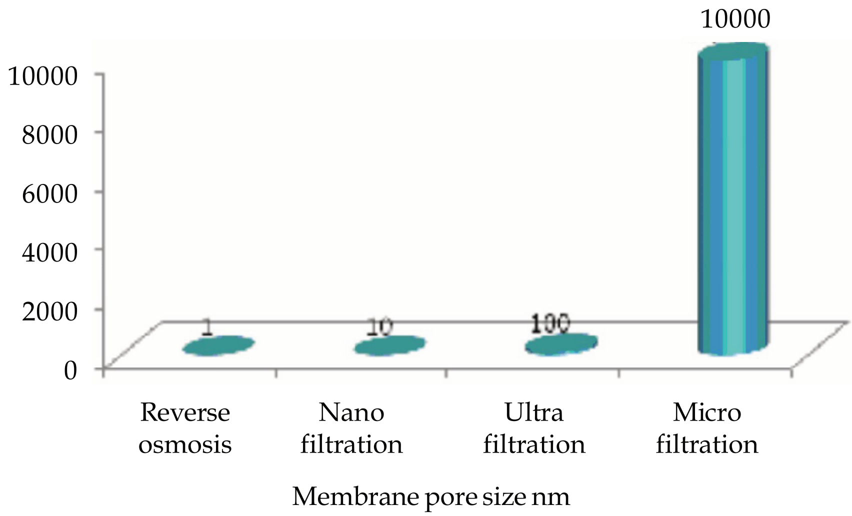

Fig. 4 : Classification of pressure driven membranes based on pore size

b. Application of Supercritical Fluid Extraction (SFE) for waste minimization by recovery of valuable compounds from solid waste

Supercritical fluid extraction (SFE) with natural CO_2 is a promising technology for recovery of valuable compounds from solid wastes and can be considered as an environmental friendly solvent-free extraction method that results in minimal oxidative and thermal stress. With SFE, high-value oils as well as aromas can be fully recovered in their natural composition. For these high-value compounds, SFE is not only the most favourable but also the least expensive method of production [38].

C. Waste treatment technologies

The treatment of most of the wastes arising from food processing industries is comparatively easier as compared to those arising from other industries due to the biodegradability of most of the effluents from agro-based industry. Almost all the conventional biological treatment systems employed in sewage treatment, such as anaerobic/aerobic lagoons, activated sludge processes, trickling filter, septic tanks, land treatment systems etc., are applicable to agro-based industrial effluents as well [2].

According to Joshi [25], the basic need for the waste treatment arises from the following points:

a. Prevention of pollution of natural streams to preserve health of citizens

b. Obligations under the Pollution Control Legislation

c. As a part of national environmental policy

It is, therefore, very important either to reduce the generation of wastes or to treat them in such a way that they do not create any imbalance in the environment. There are basically three types of wastes which are produced and are required to be treated before their disposal i.e. waste water, air pollution, and solid wastes (Table 10). Various waste water treatment strategies have been described in detail in the literature [25, 26]. Some of such technologies have been given in Table 11.

Table 10: Application of membrane filtration processes

Reverse Osmosis	Nano-filtration	Ultra-filtration	Micro-filtration
• Desalination • Concentration of food juice and sugars • Concentration of milk.	• Removal of micro-pollutants • Water softening • Wastewater treatment.	• Concentration of milk • Recovery of whey proteins • Recovery of potato starch and proteins • Concentration of egg • Clarification of fruit juices and alcoholic beverages.	• Cold sterilization of beverages • Clarification of fruit juices, beers and wines • Continuous fermentation • Separation of oil- water emulsions • Wastewater treatment

Source: Adapted from Ref [38]

Table 11 : Food processing industrial waste management technologies

Technology		Food / Products/ Operation	Reference
A.	***Waste Water Treatment***		
i.	Caustic peeling technology	Potato, fruits and vegetables	[21, 26]
ii.	Replacement of water cooling with air cooling	Blanching	[25]
iii.	Preparation of by products		
a.	Lactose from whey	Cheese industry	[25]
b.	Pectin from apple waste	Apple processing industry	[23]
c.	Essence from citrus peel	Citrus processing industry	[25]
d.	Alcohol from apple wastes	Apple processing industry	[16, 19, 26, 27, 29]
e.	Feed from apple pomace	Apple processing industry	[25]
f.	Single cell proteins	Food processing industry	[17, 26]
g.	Mushroom soup and chutney	Mushroom processing wastes	[26]
iv.	End of pipe waste water treatment	All food processing industries	[25]
v.	Aerobic biological treatment	Waste waters	[10, 25]
vi.	Anaerobic biological treatment	Waste waters	[26]
vii.	Combined aerobic and anaerobic biological treatment	Waste waters	[25, 26]

contd...

B. ***Air Pollution***			
i.	Dilution	Air emissions	[25, 33]
ii.	Use of pure fuels, washed coal, improved combustion process etc	Air emissions	[25, 33]
iii.	Dry and wet particulate control systems	Air emissions	[25, 33]
C. Solid waste			
i.	Drying and blending with nutrients to produce cattle feed	Fruit and vegetable processing wastes	[25]
ii.	Vermi-composting	Food industrial wastes	[25]
iii.	Preparation of by products	Most industries	[41]

1.6. Legal and Environmental Issues

While it is true that the principle of waste prevention is universally accepted, the practice has lagged far behind. Food industry will also have to concentrate on waste avoidance as well as utilization of process wastes. Application of clean technologies enhances the safety and quality of the product as well as reducing the energy requirements and environmental impact of the food industry. The main environmental impacts of the food sector are aquatic, atmospheric and solid waste emissions. By choosing proper separation technology, wastewater treatment is usually carried out and is implemented in process installations. The atmospheric emissions are mainly caused by extensive energy use. The food industry consumes a great deal of energy for heating buildings, processes, and process water, for refrigeration and for the transportation of raw materials and products. The increased share of renewable energy sources could slowly reduce the amount of conventional fossil fuel utilization. Solid by-products and wastes are also generated in high amounts in the food industry. The main treatment method of solid wastes is, at present, composting. Recovery and re-use of by-products and wastes as raw materials is another option. However, microbiological quality and safety is always of major concern [38].

The amount and quality of the effluent greatly influences the economic feasibility of a company. Besides minimizing the use of water, efforts should be made to do the following according to World Bank [44]

- Use dry methods such as vibration or air jets to clean raw fruit;
- Separate and re-circulate process wastewaters;
- Minimize the use of water for cleaning purposes;

- Remove solid wastes without the use of water; and
- Use counter-current systems where washing is necessary.

Solid wastes usually originate from pre-treatments i.e. washing, peeling and sorting etc and they consist of damaged fruits, peels, stems, stalks, seeds, pulps etc. In a fruit and vegetable processing industry. peels, are separated from the fruit juice. Companies face the problem of the treatment and disposal of solid wastes from food processing. For example, the skins of potatoes are a source of problems, and potato processing companies are interested in the development of utilization pathways to eliminate soluble starch from wastewater, as they tend to clog the pipes [32]. Another perceived innovative technology development need is called upon for the utilization of solid wastes from the juice pressing operation. The remaining waste after the berry pressing and separation process steps, i.e. peels and seeds, do contain valuable compounds such as flavonoids or aromatic oils. When applying proper extraction technology, i.e. super-critical fluid extraction, these healthy compounds can be recovered and applied either by the food industry, or the cosmetic or pharmaceutical industries [38].

Environmental legislation is *the legal tool which* is *used to control and regulate environmental pollution from industries and development sector and is regulated by environmental authorities*. *Water* (Prevention and Control of Pollution) *Act,* 1974 was the first enactment by the Parliament in this direction of checking the degradation of our environment. Under this Act, Central Pollution Control Board and State Pollution Control Boards are set up to combat environment pollution. Prevention and Control of Pollution Act 1981 was enacted. In addition to water and air pollution, solid waste pollution to prevent land pollution, safe storage and handling of chemicals, hazardous microorganism etc. were added in 1989 to the *Environment* (Protection) *Act,* 1986. Under these acts, one of the major function of the regulatories agencies is to lay down discharge/emission standards for industries. Food processing industries are required to implement these legislations and obey all directions of the regulatory agencies. The violations of various clauses of these acts may invite stringent penalties which may include imprisonment upto a period of six years with heavy amount of fines. The details of these legislations have been provided in the literature [7, 11, 22, 25, 30]. Some of the standards for waste water disposal are depicted in Fig. 5.

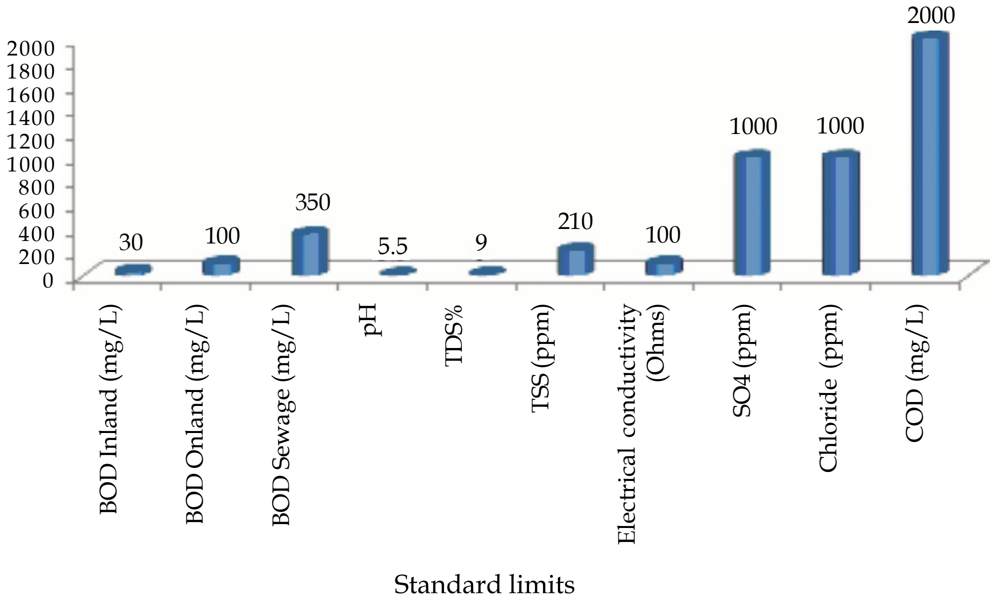

Fig. 5 : Standards for waste water disposal set by environment protection agency.
Source: Adapted from Ref [18, 20, 24]

1.7 Measuring Wastes and Pollution

For adoption of any of the waste management measures it is very important to measure the wastes generated and their pollution potential. One of the common ways of measurement of wastes would be the quantity of wastes generated i.e. Kilo litres of waste water released or tonnes of solid wastes generated etc. Obviously as a thumb rule more the quantity of wastes more would be the pollution.

Another way of measuring pollution would be to measure some of the quality attributed of wastes. Following are some of such characteristics.

a. *Biochemical oxygen demand (BOD)* : BOD is a measure of the amount of oxygen consumed by natural, biological processes that break down organic matter. High levels of oxygen-demanding wastes in waters deplete dissolved oxygen (DO) thereby, endangering aquatic life.

"BOD is the measured amount of oxygen required by acclimated microorganisms to biologically degrade the organic matter in the waste water to CO_2 and H_2O in a closed system. Oxygen consumed or biological oxygen demand is proportional to the organic matter converted. The test for BOD is limited to 5 days when about 95% or more oxygen requirement has been met and BOD test conducted at a temperature of 20°C has become a standard test to measure the organic pollution [24]".

b. *Chemical oxygen demand (COD)* is a measure of the oxygen consumed when organic matter is broken down chemically rather than biologically.

   In environmental chemistry, the COD test is commonly used to indirectly measure the amount of organic compounds in waste water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers), making COD a useful measure of water quality. COD is measured in ppm or mg/L, i.e. mass of oxygen consumed per liter of solution.

c. *pH*: Waste waters released from various industries and during various process stages vary between 2.9 to 9.4 [10]. Extremely acidic or alkaline pH would not allow the microorganisms to degrade the organic wastes biologically. Therefore, the waste treatment technology would either include :

   i. Alteration of pH so that it comes within the preferred range of microorganisms

   ii. Use of another microorganisms which can grow in extreme pH ranges

   iii. Use of chemical methods of degradation

d. *Dissolved Oxygen (DO):* More the DO better will be the survival of degradative aerobic microorganisms and *vice versa.* Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes requires sufficient oxygen levels for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. The lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills. Dissolved oxygen is very much essential for the survival of all aquatic organisms (not only fish but also invertebrates such as crabs, clams, zooplankton, etc). Moreover, oxygen affects a vast number of other water quality indicators, not only biochemical but sensory ones also like odour, clarity and taste [4].

e. *Toxins*: Presence of toxic chemicals to microorganisms in the wastes would make its biological degradation difficult.

1.8 Conclusion and Future Thrust

It is now apparent that food processing industry is the second largest generator of wastes into the environment only after the household sewage. The generation of biodegradable waste, increased linearly with the growth and development of food processing industry. The waste from food processing industry is a rich source of many utilizable components. It has also been proven by many researchers that a number of by-products i.e. pectin, alcohol, vinegar, animal feed, colours, essence etc. can be manufactured from various types of food processing wastes, besides reducing pollution problems. Prevention of waste generation, its minimization, manufacture of by products and environmental friendly waste treatment would not only generate additional income but would also reduce the cost which would otherwise have incurred on waste treatment and disposal. The food industry waste has been proved of real economical value be employing micro-organisms for its conversion into useful products, use of genetically engineered microbes is a novel idea to enhance the yield and quality of the products prepared. An integrated approach would be the priority for efficient waste utilization prior to treatment.

Despite of the fact that specific standards have been fixed by various environment protection agencies world over to control pollution, and a number of technologies for waste minimization, waste treatment and safe disposal have been developed, the food processing has not given a serious thought and preference for waste management. Presently we process only 1.8 to 2 % of our production and the quantity of wastes generated are huge. It would be wise if we think right now of what shall happen when the processing levels would reach 8-10 % or more as targeted by the Ministry of Food Processing Industries, Govt. of India. Government should also try to encourage the food processing industries to set up waste utilization plants by offering some concessions, subsidies etc. Nevertheless, time is not far away when the industrialists would themselves realize the economic potential of such units, and would become more environment conscious leading to adoption of latest technologies for better utilization and management of food processing industrial wastes. Any step ahead shall require the "*will to do*".

References

1. Anonymous (2006) World's shortest comprehensive USA/Canada recycling guide. http://www. obviously. com/recycle/guides/shortest.html
2. Anonymous (2008) Central Pollution Control Board. www.cpcb.nic.in
3. Anonymous (2009) www.@gri-Infotech.com
4. Anonymous (2008a) Lenntech Water treatment & air purification Holding B.V. Rotterdamseweg, Netherlands (http://www.lenntech.com/ why_the_oxygen_ dissolved _is_important.htm)
5. Anonymous (2008b) Waste Framework Directive (European Directive (WFD) 2006/ 12/EC) http://www.aggregain.org.uk/waste_management_regulations/ background /definition_of.html
6. Anonymous (2008c) Cashing in on Climate Change, *IBISWorld, March 2008, http:// www.ibisworld.com/pressrelease/default.aspx*

7. Anonymous (1992) Pollution Control Law Series PCL/2/1992. CPCB, Pub., New Delhi.
8. APEDA (2000) *APEDA Export Statistics and Annual Report 1999-2000,MFPI*
9. Bakthavatsalam V (1999) The Indian market for sustainable energy. *IREDA News* 10(3): 11–19
10. Barnes D, Forster CF & Hrudey SE (1984) *Surveys in Industrial Waste Treatment.* Vol. I. Food and Allied Industries. Pitman Pub. Co. Ltd., London.
11. Bartrain J & Balance R (1996) Water Quality Monitoring, E and FN SPON, London
12. CIWM (2009) Chartered Institution of Waste Management, UK. http:// www. ciwm. co.uk/ pma/1384
13. Converti A, Perego P Borghi MD & Ferraiolo G (1989). Pre treatment operations and alcohol fermentation of orange wastes. *J. Fermentation Bioengg.* 68(4):277.
14. FAO (2006) www.fao.org
15. FAO (2009) Statistical Database of the Food and Agricultural Organization, Rome, Italy. www.fao.org (page visited on 14th Nov 2009)
16. Ghosh S & KLass DL (1978) Two phase anaerobic digestion. *Process Biochem.,* 13 (4). 15.
17. Green JH & Kramer A (1979) *Food Processing Waste Management.* A VI Pub. Co. Inc. Westport, CT
18. Gupta K & Joshi VK (2000) Fermentative utilization of wastes from food processing industry, *In:* Postharvest Technology of Fruits and Vegetables. Verma, L.R. and Joshi, V.K. (eds.) Indus Pub. Co., New Delhi.
19. Hang Y D, Lee CY & Woodans ED (1982) A solid state Fermentation system for Production of ethanol from Apple Pomace. *J Food Sci.,* 47: 1851.
20. Hang Y D (1979) Production of single cell proteins from food processing wastes. In: Food Processing Waste. J.H. Green and A. Kramer (eds.). AVI Pub. Co., Westport. CT, p442.
21. Hart, Graham RR, Hoxsoll CC & Williams GS (1970) An experimental dry caustic peeler for cling peaches and other fruits. *J. Food Sci.* 25:839.
22. Henry JG & Heinke GW (1989) Environmental Science and Engineering. Printice Hall, Englewood Cliffs, New York.
23. Jain RK, Ghankrokta SS & Agrawal JA (1984) Isolation and Characters of Pectin from apple Pomace. *Indian Food Packer,* 38 (6): 65
24. Johar DS, Krishnamurthy GV & Bhatia BS (1960) Utilization of apple pomace. Food Sci. 9:82.
25. Joshi C (2000) Food processing waste treatment technology, *In:* Postharvest Technology of Fruits and Vegetables. Verma, L.R. & Joshi, V.K. (eds.) Indus Pub. Co., New Delhi.

26. Joshi C & Joshi VK (1990) Food Processing Waste management Technology – need for an integrated approach. *Indian Food Packer*, 44 (5):56.

27. Joshi VK & Sandhu DK (1996) Preparation and evaluation of an animal feed byproduct produced by solid state fermentation of apple pomace. *Bioresources Technol.*, 50: 251.

28. Joshi VK & Sandhu DK (1996b) Effect of type of alcohols in the distillate form the soild state fermentation of apple pomace of different yeasts. *Natl. Acad. Sci. Letters.*,49(11 & 12): 219.

29. Joshi VK, Pandey A & Sandhu DK (1999) Fermentation Technology for food industry waste utilization. In: *Biotechnology: Food Fermentation* (Microbiology, Biochemistry and Technology). Vol. 2. V.K. Joshi and Ashok Pandey, (eds.) Educational Publishers and Distributors, New Delhi. p. 1291-1348.

30. Mahajan SP (1985) Pollution Control in Process Industries. Tata McGraw Hill Pub. Co., New Delhi

31. Maini SB. & Sethi V (2000) Utilization of Fruit and Vegetable Processing Wastes, *In*: *Postharvest Technology of Fruits and Vegetables : Handling, Processing, Fermentation and Waste Management,* Vol 2 (Verma, L. R. and Joshi, V. K. eds.) Indus Pub. Co., New Delhi, pp1006-1018.

32. Marakassi (2002) Technical Report 2002. Vikki Food Centre, University of Helsinki, Helsinki, Finland.

33. Muralikrishna KVSG (1995) *Air Pollution* & *Control.* Kanshal and Co., Kakinada, India

34. Nigam P & Pandey A (1986) Utilization of by-products of cane sugar industry. *Cooperative Sugar* 17(7):529.

35. Odunsi AA, Akande TO, Yusuph AS & Salami RI (2002) Comparative utilization of high inclusion rates of four agro-industrial by products in the diets of egg type chickens. Archivos-de-Zootecnia. 51(196):465-468.

36. Pandey A & Kumar SS (1990) Treatment of high strength plantation effluents- a management approach. *Encology* 4(9):16.

37. Panday GN & Carney GC (1989) *Environmental Engineering*. Tata McGraw Hill Pub., Co New Delhi.

38. Pap N, Pongrácz E, Myllykoski L & Keiski R (2004) Waste minimization and utilization in the food industry: Processing of arctic berries, and extraction of valuable compounds from juice- processing by- products. *In:* Proceedings of the Waste Minimization and Resources Use Optimization Conference. Pongrácz E. (ed.) June 10th 2004, University of Oulu, Finland. Oulu University Press: Oulu. p. 159-168.

39. Rahmat H, Hodge RA, Manderson GJ & Yu PL (1995) Solid substrate fermentation of *Kloeckera apiculata* and *Candida utilis* on apple poomace to produce an improved feed stock. *World J Microbiol. Biotechnol*. 11(2):168.

40. Riemer J & Kristoffersen M (1999) Information on waste management practices. A proposed electronic framework. European Environmental Agency, Copenhagen, Denmark.

41. Sharma SK (2010) *Postharvest Management and Processing of Fruits and Vegetables – Instant Notes*. New India Pub. Agency, New Delhi 390p.

42. Stineman TL, Edward JD & Gresskoof JC (1980) Production of baker's yeast from acid whey. US Patent 4 192912 (DSA 43109 (1981).

43. Viz S & Gandhi DN (1993) Whey- an alternative substrate for the production of Baker's yeast. *Indian Food Industry* 12(5):41

44. World Bank (1996) Pollution Prevention and Abatement: Fruit and Vegetable Processing. Draft Technical Background Document. Environment Department, Washington, D.C.

2

Impact of Food Industrial Waste on Environment

Shachi Shah, V Venkat Ramnan & SK Sharma

2.1 Introduction

Each step in the food industry system e.g. food production, processing, transportation, storage, distribution and marketing, has some impact on the environment and there is much concern about environmental pollution. Due to the highly diversified nature of the food industry, various food processing, handling and packaging operations create wastes of different quality and quantity, which, if not treated, could lead to increasing disposal problems and severe pollution problems [24]. The preservation of the natural environment from industrial pollution is currently receiving much attention. In food industry, the most important problem is treatment and disposal of large quantities of waste water, a by-product of various processing operations. It is one of the largest industry groups comprising the manufacturing sector of the U.S. economy [47]. Likewise, India is the world's second largest producer of food next to China, and has the potential of being the largest food processor. The total food production in India is likely to double in the next ten years [22]. Flour and grain; soft drinks and carbonated water; breweries; starch and miscellaneous food products; meat, poultry and fish; tea, coffee and other beverages; fruit juices; animal feed; sugar; distilleries and blending of spirits; cocoa, chocolates and sugar confectioneries; agricultural and food chemicals and industrial packaging are important sub-sectors of the food processing industry. Food processing projects involve the processing and packaging of meat products, fish and shell fish, dairy products, fruit and vegetables, grains and beverages production. It includes refinement, preservation, improvement of product, storage, handling, packaging and canning (Fig.1). The processing may involve receiving and storing raw or partially processed plant, animal or other food materials, processing the raw materials into finished products, packaging and storing the finished products.

The processing industries are a part of our environment and are often major generators of wastes. Since the existing environment within which they operate is the only one we have, and shared by both the consumers and operators of other sectors of the economy, there is the need therefore, to ensure the preservation of the environment as natural and as ecologically balanced state as possible for the use of all. Industrial waste is a major source of environmental pollution that affects the geology, soil and ecology of an area. The food industries should be aware of the contents of the wastes they generate with the view to making them environment friendly [25].

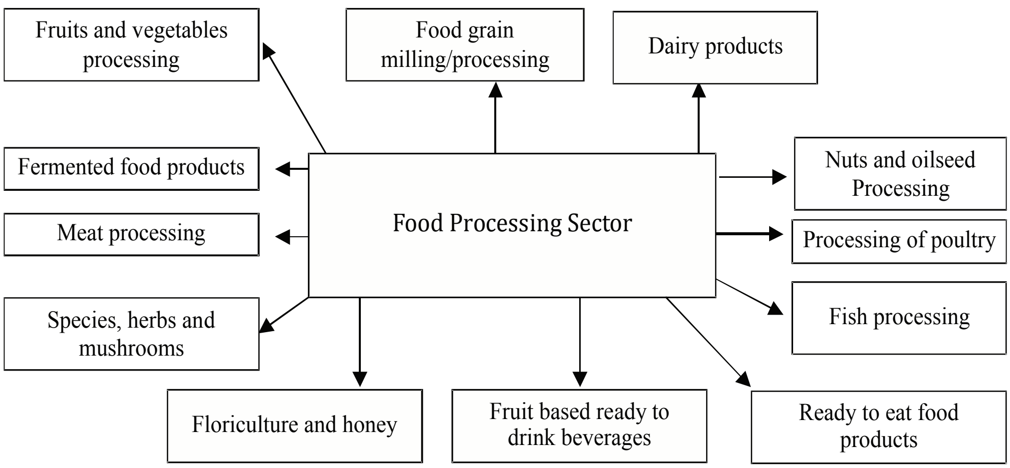

Fig. 1. Food processing sectors. *Source :* Ref.[24]

Food processing industries produce the countless products and that will continue to produce waste of various kinds. With a large number of facilities, it is important that this industrial sector properly manages different waste streams that may be generated. Wastes from air emissions, process water, and a variety of solid and hazardous wastes must be managed in accordance with applicable regulations [1]. Prevention of pollution should play an important role in minimizing many of these harmful wastes. There is a growing need for food processing facilities to understand and comply with environmental regulations in order to avoid consequential enforcement actions and/or fines as well as potential harm to human health and the environment [11].

2.2 Key Resources Used by Food Processing Industry

Key resources used by the food processing industry include the water, raw materials and energy.

2.2.1 Water

Traditionally, the food-processing industry has been a large water user. It is used as an ingredient, an initial and intermediate cleaning source, an efficient transportation conveyor of raw materials, and the principal agent used in sanitizing plant machinery and areas. Although water use will always be a part of the food-processing industry, it has become the principal target for pollution prevention and source reduction practices.

The food-processing industry utilizes water as outlined earlier to meet its individual day-to-day needs. As much as fifty per cent of the water used in the fruit and vegetable sector is for washing and rinsing. The meat processing sector has minimum requirements set by the United States Department of Agriculture (USDA) on the amount of water required to clean poultry products. Water is the primary ingredient employed in products for the beverage and fermentation sector, and dairies utilize water as the standard cleaning agent for process machinery. Although water use will always be a part of the food-processing industry, its reuse and subsequent generation of wastewater have become the principal targets for pollution prevention practices. Water used in conveying materials, plant cleanup, or other no ingredient uses are the main areas of potential reduction being considered by the entire food-processing industry.

2.2.2 Raw materials

Most of the food-processing facilities are located close to their agricultural source. For these facilities, there is usually one chief raw material that makes up the largest percentage of the final food product's composition. The exception to this is the beverage sector, which is the most similar to a true "manufacturing industry," that is, one in which the product is created from a combination of raw materials. The same can be stated for specialty food products. Confectionery, baked goods, and other luxury products involve much more elaborate manufacturing processes. Typically, specialty food processing uses less water and utilizes base materials that have been preprocessed before they enter their specialty production process.