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Technological Innovations for Waste Management in Food Processing Industry: An Overview

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***Abstract*—In the modern world, food-processing industry holds an important position. Its major sectors include fruit and vegetables, meat, poultry, seafood, beverage and bottling, and dairy operations. In due course of food production, both wastewater and solid waste are generated. In spite of using biodegradable and recyclable products, still a separate processing system is required to manage the waste generated in the food processing industries. Nowadays, food processing industries need to ascertain that their ongoing methods to process raw material into valuable product, overall management and even, disposal of food waste is environment friendly. This paper gives an overview of food waste management. It emphasizes on the various issues and concerns of food waste, along with the different technological innovations, including the involvement of computer simulations in managing food waste. Challenges and opportunities gives insight for development of technologies for more efficient management and treatment of food waste.**

***Keywords*—food waste; waste reduction; waste management; primary treatment; secondary treatment**

I. Introduction

Food processing industry is one of the most important and developing section in the socio-economic domain. Processing of food is conversion of raw ingredients directly into food or food related forms. For example, Corn Starch Industry processes corns to give by-products like starch, oil etc. Corn kernels obtained after processing is rich in carbohydrates, proteins, oil and fibre with some traces of minerals. This sector has the potential to influence growth and is critical for the socio-economic growth of a country. Food Processing Industry is aimed to feed billions of people with nutritious and non-toxic food [1].

India is known to be a significant producer of food in the world and so food processing industry serving as a bridge between agriculture and industry is very vital for India's development. Surveys indicate that India has high potential in the food processing industries. Food Processing Industry is also a well known sector to provide job opportunities to various rural and poor population in India. In 2011, the food processing sector in India was estimated around USD 180 billion; by 2020, the size is expected to reach USD 530-550 billion. More production would lead to generation of more waste. Food wastage is a matter of great concern. Food processing units now aim to invest in R&D not only to improve yields and preserve the nutrients but also to reduce wastage. These sectors also need to adopt different policies related to maintenance of better environment ([1] - [3]).

In India, there are different food processing industries like Dairy, Fruits & Vegetables, Grains & Cereals, Corn Starch, etc. These food processing industries are very beneficial to human population but various challenges are faced by these industries. Challenges appear in terms of profitability of the industries. Challenges also come up across various procedures adopted within the industry; collection, treatment and disposal of waste need to be environment friendly as well.

It is estimated that reduction in wastage would add about thousands of crores to national savings. In Fruit and Vegetable Sector only, 30% wastage amounts to about Rs. 25,000 to Rs. 30,000 crore. If initiative is taken to recycle this huge amount of biodegradable waste via different environment friendly methods, like composting, then high quality organic manure can be generated which would finally help in increasing the yield of healthy crops[2]. Thus, technological solutions for waste management would be in high demand to maintain a proper environmental condition.

II. Major Challenges & Issues of the Food Processing Industries

Food processing sector is a budding industrial section. At the same time, there are certain concerns in this sector that are outlined here.

A. Solid Waste Generation: Generation of solid waste from food processing units like hotels, has an impact on the environment as the improper handling and disposal of waste leads to emission of harmful greenhouse gases like carbon dioxide, methane and ammonia. Besides, obnoxious smell can also be generated due to inappropriate disposal technique.

B. Wastewater Reduction and Treatment: In food processing industry, majority of waste is produced in the form of wastewater during processes like cleaning, washing, manufacturing, etc. The biggest challenge is to manage this

wastewater and treat it effectively so that some portion of the wastewater can be reutilized again [4].

C. Pollution from Food Processing Industries: The generation of solid waste or wastewater cause environmental pollution. Disposal of these waste into landfills are harmful for both the land and water in which they are disposed as they deteriorate the physicochemical properties of soil as well as water, making it undesirable for consumption and growth of plants. Along with this, the waste also releases harmful gases that pollute the air.

D. Technological Innovations: The lack of technical equipment for the management and treatment of solid waste and wastewater is a major challenge and concern of the food processing industries. The use of technical instrument can enhance their treatment and will reduce waste generation, too.

III. Techniques involved in Solid Waste Management of Food Processing Industry

Effective Solid Waste Management (ISWM) can possibly solve major challenges of the food processing industry. This scheme is a combination of appropriate selection and application of technologies, set of rules and regulation along with management programmes to obtain effective waste management. The hierarchy of ISWM is shown in Fig. 1.

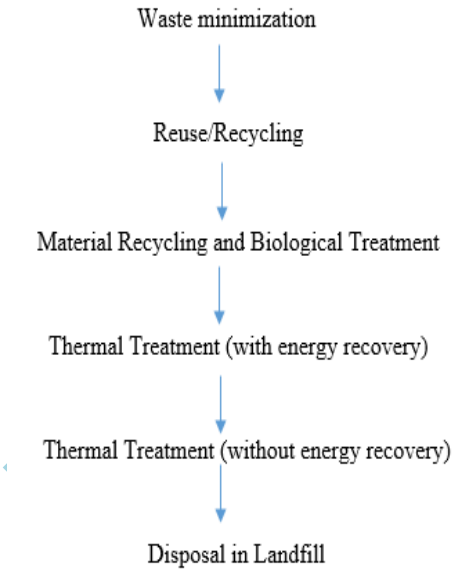

Fig. 1. Scheme of Effective Solid Waste Management.

The flowchart indicates the various essential steps that can be followed effectively using various methodologies to handle food waste, particularly solid, in efficient manner. Firstly, Waste Minimization can be achieved by volume reduction and strength reduction of the waste. Secondly, Material Recycling can be achieved by development and implementation of MRFs (Material Recovery Facilities). These facilitiesare used for processing of source-separatedwaste that is obtained from drop-off and buy-back centres. Refuse Derived Fuel (RDF) is a combustible portion of the raw waste that is being separated for burning as fuel. Next, the waste generated can undergo biological treatment. Composting is defined as the biological decomposition of waste that is converted into organic manure under controlled conditions of moisture, temperature, etc. Composting can also be achieved by use of earthworms, known as Vermicomposting.

Waste can also be thermally treated via different methods like Pyrolysis, Gasification, Incineration. In pyrolysis, waste is burnt in absence of oxygen at 200 ^{o}C -900 ^{o}C. Gasification is the process in which partial burning of waste takes place in presence of little oxygen at 1000 ^{o}C. Incineration leads to burning of waste in presence of oxygen at very high temperature in the range of 1000-1200 ^{o}C [5]. Disposal of waste from food processing industries can be done in sanitary landfills.

IV. Techniques involved in Wastewater Management of Food Processing Industry

There are various methods to treat the wastewater generated [6]. One of them is Activated Sludge Process (ASP). Microorganisms like bacteria, fungi, cyanobacteria, protozoa and algae areadded to the wastewater tank. Oxygen is mechanically supplied to bacteria that feed on organic material and in due course, the waste is treated. This is a sophisticated process with many mechanical and electrical parts, which needs careful operator control. This kind of method produces large quantities of sludge for disposal, but usually provides high degree of treatment [4].

In treatment of wastewater via Trickling / Percolating Filters, sewage is passed down through a loose bed of stones and bacteria on the surface of the stones treats the sewage. This process occurs in aerobic condition with oxygen available in atmosphere.

In Upflow Anaerobic Sludge Blanket (UASB) treatment method, the anaerobic microorganisms decompose the wastewater that flows upwards through a blanket of granular sludge. In this technique, organic matter undergoes anaerobic decomposition. The gas generated during the anaerobic process is collected in the specific gas collection hood at the top of the reactors [4].

Technology of Aerated lagoons is similar to Waste Stabilization Pond (WSP) but with mechanical aeration and is not a very common process. The oxygen requirement is fulfilled by mechanical aeration. This is rather a complicated process involving higher operation & maintenance cost [4].

In Oxidation ditch process, an oval-shaped channel with aeration is provided. This requires more power than WSP but less land, and is easier to control than processes such as ASP.

MBBR Technology [7] is a cost effective relatively easier treatment process with very less maintenance. In this method, many polyethylene biofilm carriers operate in mixed motion inside an aerated wastewater treatment basin and each of them increases productivity by providing protected surface area to support the growth of heterotrophic and autotrophic bacteria within its cells. This high-density population of bacteria facilitates high-rate biodegradation.

These technologies can be utilized in various food processing industries for management of wastewater. Here, a flowchart illustration has been shown for waste treatment at a dairy farm [6]. The flowchart clearly indicates the primary and secondary treatment methods opted to treat dairy waste.

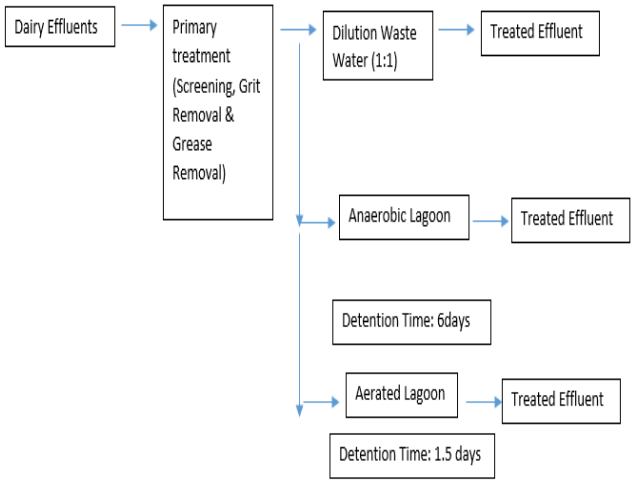

Fig. 1. Process Flowchart for Treatment of Dairy Effluents.

In treatment of waste from dairy industries, both primary and secondary treatment units consisting of biological treatment units like aerated lagoon have been utilized. Similarly, different food processing industry can utilize the combination of primary and secondary treatment units to treat and manage their waste. [(8]-[9])

V. Role of Computational Technologies in Management of Food Waste

IT plays a significant role in management of food waste. Artificial Intelligence can be utilized to formulate a difficult problem into a model that further gives better cost benefit analysis. Some of the modelling simulation techniques can also enhance the management and treatment of this waste. Some softwares like Genetic Algorithms (GAS), Artificial Neural Networks (ANNs), Decision Tree (DT), Fuzzy Logic (FL) are popular in this regard.

Artificial Intelligence (AI) gives many benefits while its usage in the food processing industry facilitates lower cost and yields approximate solutions to the defined problems. It is also helpful in classification of crops in agricultural fields. AI aids in detection of plant disease and classification of weeds that helps in better crop management. ([10]-[11])

Information and Communication Technology (ICT) deals with wide ranges of technical innovations that contributes in different parts of management like gathering and exchange of data, processing and further transmission of data [12]. In essential solid waste management processes, like, waste segregation, application of appropriate treatment methodologies, involvement of ICT is dominant.

Simulation Techniques are being utilized to assess the possibilities of dynamic waste collection. This would increase the logistical efficiency and customer service that in turn would benefit in terms of lesser traffic congestion on the roads for waste collection and, thus, lesser emission of carbon dioxide gases. A number of studies are dedicated to specific waste collection strategies. A common approach to model this process of waste collection is via Vehicle Routing Process (VRP). Even in the food processing industries, there is a high demand of regular waste collection, so, via efficient waste collection strategies, there would be both economic and environmental benefit. ([13] – [17])

Based on optimization techniques and routing problems, NERUDA model was developed to facilitate waste transport in Czech Republic in collaboration with Brno University of Technology. Initially, algorithm called POPELAR was developed for optimizing waste collection. It was based on genetic search using C++ language [18]. Computer-based numerical models may play an essential role in this regard. A system dynamics based simulation system for plastics waste management, EcoSolver IP-SSK has been developed to transport, collect, sort and treat waste; sub-models for the ecological and economic assessment are also included [19].

Genetic Algorithm is another popular simulation approach to identify optimal routes for Municipal Solid Waste Collection. This kind of waste management is based on geo-referenced spatial database supported by a geographic information system (GIS) that accounts for all the required parameters including static data like position of the waste collecting bins and dynamic data like road network and related traffic. Statistical scrutiny is carried out to assess inter-relations between dynamic factors. Following such a strategy, both financial and environmental benefit can be achieved. Inspired by Darwin's theory of evolution, John Holland and his colleagues invented Genetic Algorithm (GA). This kind of algorithm uses genetic operators like selection, crossover, mutation for finding solutions to complex problems ([20] - [21]).

A genetic algorithm (GA) combined with simulation (S) generated a technique named GAS which provided solutions to the problem of municipal waste flow under uncertainty. This investigation showed that using evolutionary algorithm along with simulation can provide an effective solution for collection, allocation and disposal of municipal solid waste in the municipality of Hamilton-Wentworth [22].

VI. Conclusion

Managing the waste is in itself a big challenge and it is difficult to suggest any one particular method to be followed at one specific unit. Based on the volume of waste generated at a site, a specific plan can be schemed in order to handle the waste generated. An effective plan would usually be a combination of different scientific techniques. Various kinds of simulation techniques can be incorporated into the scheme as required for better eco-friendly and automatized waste management in different food processingunits. All such environment friendly waste management plans and techniques will contribute towards sustainable development of the society.

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