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Invited Review Article

Life cycle assessment and application of green technologies in dairy industry to reduce carbon footprint

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Abstract

The demand for sustainable dairy production and processing is increasing day by day. Dairy sector is considered as a hotspot in the environment footprint scenario due to emission of greenhouse gases (GHG), depletion in natural resources etc. Maximization of societal benefits, improvement in peoples' socio-economic conditions along with decrease in the adverse effects on the environment have, therefore, been emphasized by scholars. The life cycle assessment (LCA) studies of milk production, processing and marketing are analysed to find a way out for reducing the harmful environmental effects, which can be achieved to a great extent if green technologies comprising of sustainable, energy-efficient, environment-friendly technologies are used. Use of solar-powered electricity, non-thermal techniques such as high-pressure processing, pulsed electric field, radio frequency processing, pulsed UV light processing, bactofugation, ultrasound processing, irradiation, cold plasma, ozone treatment, enzymic hydrolysis, membrane processing etc. in the dairy industry has the potential to mitigate environment related issues. However, some of the above stated technologies may release GHG as it consumes electricity during their operation. Better utilization of dairy by-products, such as whey, buttermilk, ghee residue etc., can greatly reduce the environmental load. Treatment of dairy effluents and its reuse would decrease the depletion of natural resources and impact on the environment. The concept of green technology has already been accepted by the Indian dairy industry, but its proper implementation is still in infantile stage and needs up gradation.

Key words: Carbon footprint, Dairy industry, Environment, Green technology, Life cycle assessment

Highlights

- The article focuses attention to the damaging impact of current operations in the dairy sector on the environment.
- The review article discusses the methodologies to assess the adverse effects on the environment by the dairy industry.
- The article reports on the available environment-friendly green technologies for application in the dairy sector to reduce carbon footprint.
- The review article suggests ways and means to reduce environmental hazards caused by the dairy industry through adaptation of non-thermal technologies and by minimizing the use of precious natural resources.
- Overall, the article aims to educate the readers about the environment related issues to make our planet a better place to live in.

INTRODUCTION

Dairy sector produces the highest environmental footprint in food industry (Munir *et al.*, 2014; Notarnicola *et al.*, 2017). Cattle farm alone generates 20% of the total greenhouse gases (GHG) emitted by the livestock sector, which in turn is responsible for emission of about 14.5% of total human-induced GHG (Gerber *et al.*, 2013). Since milk is an excellent source of nutrients, its quality starts deteriorating within a few hours after milking, mainly due to microbial growth. To

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maintain freshness, milk has to be chilled to below 10ºC (preferably below 4ºC) as soon as possible enabling its easy transportation to the dairy plants for processing of milk and milk products. Milk processing mainly involves heating and cooling, temperature and time combination which vary depending upon the type of the product prepared. During heating and cooling, a large amount of electricity is consumed, which in turn increases heat generation and carbon dioxide emission. To reduce the adverse effect, eco-friendly non-thermal processes such as high-pressure technology, pulsed electric field, radio frequency processing, pulsed UV light, bactofugation, ultrasound, irradiation, cold plasma, ozone treatment, membrane technology etc. can be used after suitable modifications, as these processes cause less nutritional loss, consume less energy and bring about little changes in the organoleptic properties of the dairy products (Pereira and Vicente, 2010; Debnath and Sanyal, 2012; Debnath and Singh, 2017; Kaptan and Keser, 2018; Singh and Debnath, 2019; Hazra *et al.*, 2020). To help in achieving the imaginary concept of a green planet, different sectors engaged in food production and processing must use as many green technologies as possible.

Life cycle assessment of dairy operations

Life cycle assessment (LCA) is a tool that systematically analyses the greenhouse gas emission and the other potential environmental impacts of a product during its entire life cycle. Carbon footprint is a measure of the quantity of greenhouse gases, especially carbon dioxide which are released into the environment due to human activities. The adverse impact of each stage in the dairy sector beginning with raw milk production to processing, packaging, transportation and marketing of dairy products, on the global environment has been explored. Production of raw milk and associated agricultural practices showed a significant impact on environment by diminishing the natural resources, loss in soil fertility and biodiversity, causing acidification, eutrophication, water pollution and GHG (majorly methane) emission (Fig. 1) (McMichael *et al.*, 2007; Fantin *et al.*, 2012). Utilization of energy during production, processing and distribution of milk and its products is another cause of environmental footprint. Carrying out LCA for each stage during the production of dairy products as well as their transportation is of paramount importance to lower the environmental footprint to an acceptable level. Waterway transportation produces the least amount of GHG, followed by railways and roadways. Air mode of transportation emits 40 times more GHG than waterways (Boye and Arcand, 2012). Roadway transportation, used mostly by the dairy sector, accounts for 73% of total GHG emissions (Gupta and Singh, 2016). The LCA methods as per ISO:14040 (2006) and ISO:14044 (2006) standards involve quantification of impacts of inputs and outputs at each stage to enable strategy formulation to build up sustainable and resourceful environment. Several models for LCA studies have been developed based on the system boundaries, impact categories and consequences (Baldini *et al.*, 2016; Pernollet *et al.*, 2016). The LCA processes, depending on boundary of analysis in dairy sector, are of three types such as cradle to gate, cradle to grave, gate to grave (Fig. 2). In 'cradle to gate' system, the analysis of environmental impact of any product starts from the moment of extraction of raw materials and continues till its entry at the stores. The 'cradle to grave' system involves the total analysis of environmental impact starting from raw materials extraction to the disposal phase of the products, while the 'gate to grave' system analyses the environmental footprints during the period from transportation of products to the consumer and to the disposal phase of the products.

Novel green technologies

Green technologies could be defined as a set of technologies which help mankind to

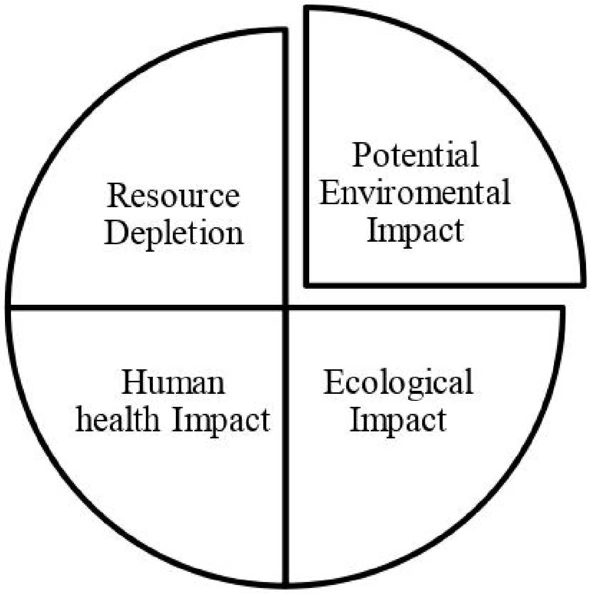

Fig. 1. Impacts of greenhouse gases released from the dairy industry

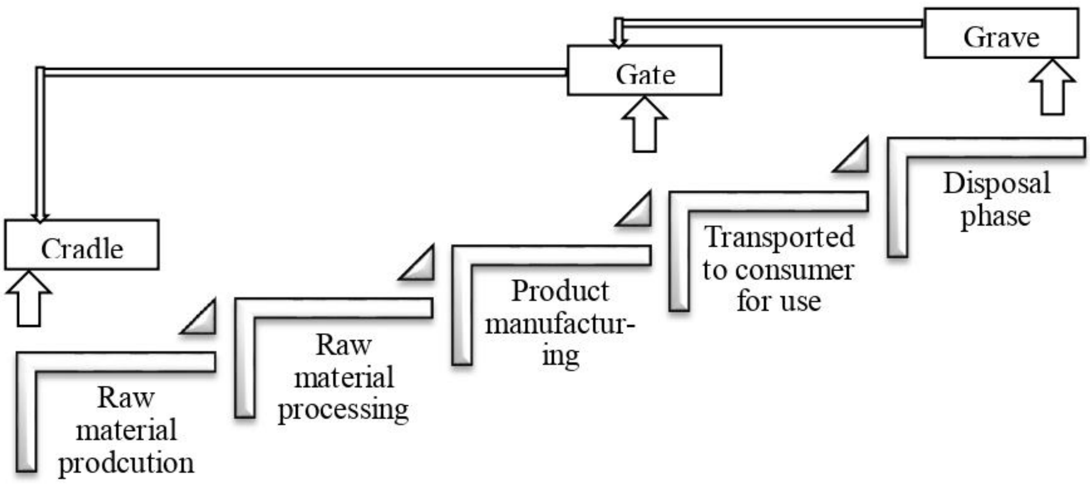

Fig. 2. Boundary of analysis in life cycle assessment in dairy industry

minimize impacts of horizontally expanding settlements over ecosystems, extract food, feed, fiber, fuel and fertilizer using renewable and non-renewable energies from the environment, facilitate climate regulation, waste decomposition and detoxification, purification of water and air, and improve livelihoods with vertically expanding habitats and to live happily with the cultural and ethnical diversity, while maintaining the ecosystem services and improving resilience (Gunasena, 2019). Green Technology uses science and technology to decrease the harmful effects of human activity on nature. Use of solar-powered heating, cooling, drying, refrigeration, air conditioning and other operations in dairy industry can reduce environmental pollution. Dairy farmers can chill bulk milk using a renewable energy device called biogas milk chiller in which biogas, derived from cow manure, powers the refrigeration unit (Edwin and Sekhar, 2018). Pasteurization and sterilization are the dominant methods in the dairy industry to destroy harmful microorganisms or diminish their deleterious effects on milk and milk products. High processing temperatures to inactivate microorganisms lower the nutritive value of dairy products and adversely influence their organoleptic quality (Wang *et al.*, 2016). Different units in a dairy plant such as boiler, refrigeration unit, water treatment plant, electricity generating sets, pumps etc., consume a lot of energy and emit GHG into the environment (Mekhilef *et al.*, 2011). Use of eco-friendly non-thermal green processes can greatly improve the situation.

Condensed milk, skim milk powder, whole milk powder, whey powder, lactose, etc., require high energy during concentration and drying. Energy consumption can be minimized by utilizing membrane filtration technology (Kumar *et al.*, 2013). Microfiltration is used mainly to reduce bacterial load in milk and whey and can, therefore, be an alternative to clarification or bactofugation unit (Gésan-Guiziou, 2010). Ultrafiltration is utilized to separate proteins from milk or whey and can be used to manufacture whey protein concentrate (Hobman, 1992). Nanofiltration technology is mainly used to demineralize whey or lactose while reverse osmosis (can operate at ambient temperature) is employed to concentrate milk by removing water (Deshwal *et al.*, 2021; Yadav *et al.*, 2022). Use of multiple effect evaporator along with thermo-compressor or mechanical vapour recompression (MVR) unit to concentrate milk requires much less energy as compared to concentration by single effect evaporator (Early, 1998). Energy requirement to evaporate 1000 kg of water from milk using a vacuum pan is 626 kWh while that in 5 or 7 effects evaporator is 126 to 180 kWh, and in 5 or 7 effects MVR is 37 to 52 kWh (Marshall, 1985). In the RO desalination and milk concentration, 4 kWh and 9-19 kWh of energy are required, respectively, for every 1000 kg of water removed (Marshall, 1985). For better heat or energy recovery in the dryer section, a three-stage dryer (a spray dryer integrated with a fluidized bed dryer) can be used instead of a single-stage dryer. Exhaust gases containing sufficient heat can be re-circulated in the dryer (Yazdanpanah and Langrish, 2011). A great environmental hazard can happen if milk solids of less than 50 micron size tend to get mixed with exhaust gases escaping the dryer (Singh, 2014). By utilizing cyclone separators or bag filters, fine milk solids can be recovered and product wastage can be minimized (Moejes and Van Boxtel, 2017).

Use of enzymes

Specific and non-toxic enzymes play a crucial role in lowering the carbon footprint in the dairy industry as they accelerate the reaction rate by lowering the requirement of activation energy (Kumar *et al.*, 2020). Enzymes like lipase, protease, esterase, lactase, transglutaminase, amylase etc., are mostly used in the dairy industry to achieve various goals such as flavor enhancement (cheese and ghee), accelerated ripening (cheese), protein cross-linking to provide better body and texture (yoghurt), prevention of lactose intolerance (lactose hydrolysed dairy products) etc. (Abada, 2019). However, the primary usage of enzymes in the dairy industry is for manufacturing cheese. Flavour development in cheese mainly occurs during ripening by proteolysis, lipolysis and glycolysis. The ripening process is energy-intensive as cheese is kept at a low temperature for an extended period (6-9 months) for optimum flavor development. Lipase, esterase and protease enzyme have been used to accelerate the ripening process and enhance flavor development by lipolytic or proteolytic pathway (Law, 2001).

Use of preservatives

Indiscriminate disposal of dairy effluents containing perishable milk solids into the environment poses a threat as these generate

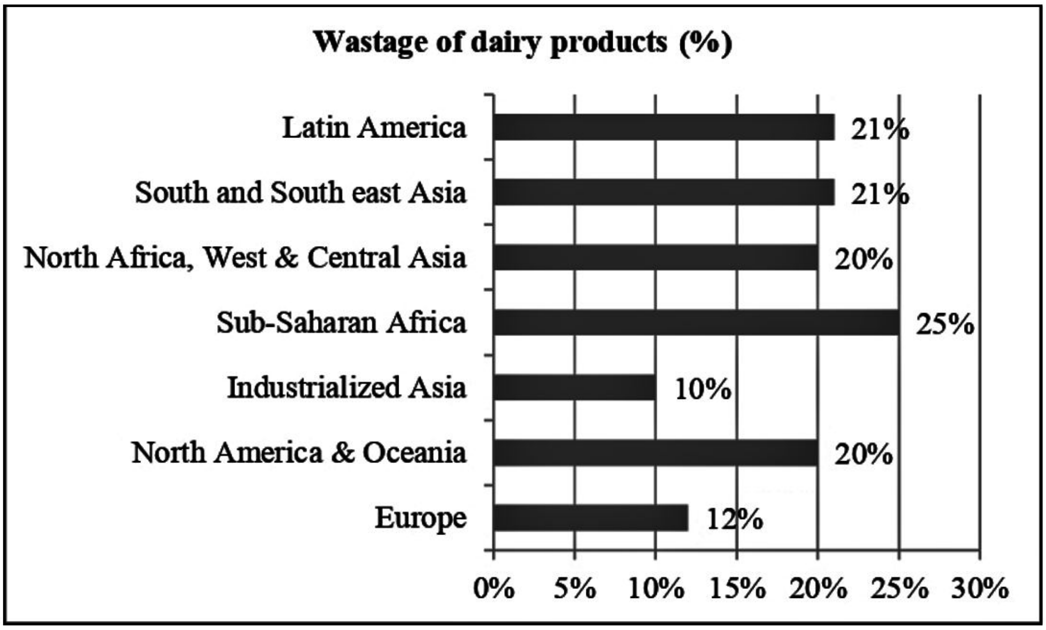

Fig. 3. Wastage of dairy products in various continents (Source: Gustafsson *et al.*, 2013)

methane gas on decomposition. Spoilage of the food product not only creates a burden in waste management but also possesses a challenge in feeding the starving population. About 828 million people are starving globally (WFP, 2022) while annual food spoilage in the world was estimated to be 1.3 billion tonnes (FAO, 2011). According to Gustafsson *et al.* (2013), wastage of dairy products was highest in Sub-Saharan Africa and lowest in industrialized Asia (Fig. 3). Enhancement of shelf life of food products using approved preservatives can provide partial solution to tackle the food scarcity problem.

Chemical preservatives such as sulphites can cause headache, allergies and many other symptoms. Similarly, sorbates and sorbic acid, the common mold inhibitors used in foods, cause urticaria and dermatitis (Sharma, 2015). To prevent detrimental health effects, utilization of bio-preservatives such as nisin, pediocin, lacticin, essential oils etc. instead of chemical preservatives in food products is gaining popularity (Table 1). Bio-preservatives can act as bacteriostatic or bactericidal agents and at the same time can exert influence to maintain the organoleptic and physico-chemical quality of milk and milk products without any adverse health or environmental impact. In nutshell, usage of bio-preservatives can be a suitable approach to achieve the sustainable development goal.

Utilization of dairy by-products

To reduce wastage of milk solids, it is necessary to utilize the dairy by-products for preparing value-added products. Incorporation of casein, caseinate and co-precipitates derived from skim milk (the major by-product of the dairy industry) into food products increases their protein contents. Industrial casein can be used to manufacture a number of products such as adhesives, paints, vulcanized rubber etc. (Badem and Uçar, 2017). Whey obtained during the preparation of chhana, paneer, casein, shrikhand and cheese is the second largest dairy by-product which can be used to prepare whey beverages, whey powder, whey protein concentrate (WPC), whey protein isolate (WPI), ethanol, bio-gas, lactose powder, single cell protein, baker's yeast etc. (Božanić *et al.*, 2014). Whey beverage being rich in electrolytes, serves the dual purpose of thirst-quenching and rehydration solution. Whey

Table 1. Bio-preservatives incorporated in dairy products

Type of bio-preservative	Source	Application	References
Bacteriocins			
Nisin	*Lactococcus lactis* subsp. *lactis*	Pasteurized milk, sterilized milk, evaporated milk and processed cheese to inhibit growth of heat stable *Clostridium tyrobutricum.*	Khurana and Kanawjia (2007)
Lactacin 3147	*Lactococcus lactis*	Accelerates ripening of cheese and eliminates gram positive microbes.	Guinane *et al.* (2005); Sen and Ray (2019)
Pediocin PA-1	*Lactobacillus plantarum*	Exhibits excellent inhibitory effect against *Listeria monocytogenes* in cottage cheese and ice-cream.	Rodríguez *et al.* (2002)
EO	Cumin, rosemary and thyme	Inhibit the growth of pathogenic microorganisms like *Salmonella typhi* and *bacillus cereus*, maintain the sensory and physico-chemical properties of ultra-filtered soft cheese and Minas Frescal cheese.	EL-Kholy and Aamer (2017); Mishra *et al.* (2020)
EO	Zataria, peppermint and basil	Restrict the growth of *Escherichia coli* and *Listeria monocytogenes* in probiotic yoghurt	Azizkhani and Tooryan (2016)
EO	Cumin and thyme	Act as anti-oxidant during storage and prevent deterioration in butter	El-Sayed and Youssef (2019)
Bacteriophages	—	Hinder the growth of *Salmonella* spp., *Staphylococcus aureus, and Listeria monocytogenes* in pasteurized milk, cheese and dahi, by producing endolysins.	Ameer *et al.* (2019)

powder is used to make up the requirement of solids-not-fat (SNF)/ protein content in various food products. Athletes and bodybuilders widely consume food items rich in WPC. Glycomacropeptide isolated from sweet cheese whey can be used for phenylketonuria patients (Sharma *et al.*, 2013). Lactose is commercially used as a filler and bulking agent in pharmaceutical applications (Hebbink and Dickhoff, 2019). It is also used in bakery products to impart flavour and colour, and in confectionary products to improve their body and texture (Chandan and Kilara, 2011). Buttermilk added with salt or spice is normally consumed fresh as a thirst-quenching beverage. Buttermilk powder can be used to make up the total solid (TS) content in certain dairy products. Owing to high phospholipids content and greater water-binding ability, addition of buttermilk powder to yoghurt prevents syneresis (Garczewska-Murzyn *et al.*, 2022). Ghee residue, which is normally thrown away, can be utilized as animal feed and to manufacture various confectionery and bakery products (Roy *et al.*, 2018).

Water utilization and wastewater management

Yield of wastewater in dairy industry is very high as it requires huge quantity of water in every stage from raw milk production to the manufacture of dairy products. Treatment of wastewater, therefore, assumes importance to address environment related issues. For each litre of milk heat treated and chilled, almost twice and thrice the amount of water gets utilized, respectively. Almost 2.4 and 3.6 lakh litre of water is used daily for thermal processing and chilling of milk, respectively in a typical dairy plant (Singh and Kumar, 2009; Irfan and Mondal, 2016). Processing of one kg of yoghurt, cheese, ice-cream and milk powder requires about 0.48-4.0, 0.48-3.9, 0.87-6.5 and 0.07-2.6 litre of water, respectively (Rad and Lewis, 2014), while Klemes *et al.* (2008) reported that almost 1.8 litre of water, on an average, is utilized per kg of milk product manufactured. About 28, 25, 16, 12, 6 and 6% of total water utilized in a typical fluid milk processing plant are required for CIP (Clean-in-Place), pasteurization, crate washing, operational processes, manual washing and cooling tower, respectively (Rad and Lewis, 2014).

Reuse of water in a dairy plant not only saves water but also decreases pollution and damaging impact on environment. In AMUL dairy, effluents discharged from the different sections are first checked for degree of pollution, and if the pollution level is low, the same is treated by membrane filtration technologies for reuse (Tiwari and Srinivasan, 2017). Otherwise, the effluent is discharged after passage through effluent treatment plant. About 47% of water from cheese whey can be recovered by utilising ultra-filtration in combination with reverse osmosis (Meneses and Flores, 2016). About 95% of water was recovered when wastewater collected from flushing and first rinse was subjected to reverse osmosis (Vourch *et al.*, 2008). The treated water was successfully used in boiler, chiller and for external washing of equipment. In addition, rainwater, after proper treatment, can also serve as an economical and additional source of water in dairy plants (Muhirirwe *et al.*, 2022). Appropriate sequence management can also reduce the number of CIP cycles in a plant. If only one packaging machine is available in a dairy plant, milk should be packed before packaging of another product, say dahi. If the opposite is done, milk packaging cannot be started without carrying out CIP, as traces of dahi particles (if present) can curdle the milk. Excessive water should not be utilised during the equipment's start-up and shutdown. Automated CIP systems and closed cooling systems can further reduce water wastage (Rad and Lewis, 2014).

Globally, 4 to11 million tonnes of dairy waste is discharged into the ecosystem (Ahmad *et al.*, 2019). These effluents contain lactose, fat, chlorides, sulphates and many other organic components, which increase their biological oxygen demand (BOD) and chemical oxygen demand (COD) values. Dairy wastewater has a BOD and pH value of 530 mg/L and 6.5, respectively, whereas the values for COD, total solids, dissolved solids, suspended solids, volatile solids and dissolved fixed solids are 790, 2532, 1803, 729, 1702 and 1562 mg/L, respectively (Patil *et al.*, 2014). The wastewater not only increases the sewage system's organic load but also reduces the dissolved oxygen content in the water reservoirs, thereby severely impacting aquatic life. In addition, these water reservoirs serve as breeding sites for mosquitoes, insects and flies, resulting in increased incidences of malaria and dengue (Al-wasify *et al.*, 2018).

Traditional methods (coagulation, precipitation, biodegradation, sand filtration and activated charcoal adsorption), established methods (solvent extraction, evaporation, oxidation, electrochemical treatment, membrane separation, membrane bioreactors, ion exchange and incineration) and emerging methods (advanced oxidation, bio-sorption, biomass and nanofiltration) can be used to remove contaminants from wastewater. Wastewater in a dairy plant is generally treated using aerobic or anaerobic biological method. The methodology for treating wastewater should be judiciously chosen as it can contribute to the emission of GHG like carbon dioxide and methane (Keller and Hartley, 2003). Aerobic treatment for decreasing COD emits almost twice the amount of carbon dioxide gas, in contrast to an anaerobic treatment which is more economical and environment friendly. Measures should, therefore, be followed to trap carbon dioxide and methane gas to safeguard the environment and produce green energy like bio-gas (Keller and Hartley, 2003). Various green or eco-friendly techniques such as membrane biological reactor, electro-coagulation, advanced oxidation processes, activated carbon adsorption processes etc., can also be used to treat wastewater (Yadav *et al.*, 2019).

Packaging

About 69% of the packaging materials is used for packaging of food and beverages, followed by 14% for clothing, 9% for educational and recreational purposes and the rest 8% for home and interior purposes (Pongrácz, 2007). Plastics derived from synthetic polymers take a long time (may be more than 500 years) to degrade, which led to development of biopolymers derived from renewable resources like mango peel, pumpkin residue, blueberry waste, whey protein, wheat straw fibres etc. (Thulasisingh *et al.*, 2021). Biodegradable plastics are degraded within a short time in the environment. However, their rigidity, flexibility, and barrier properties are considerably less as compared to synthetic plastics. Used packaging materials usually are dumped into the landfills of municipality, which leads to extensive production of GHG. Paper constituted 5.8% of the municipal solid wastage (MSW), followed by plastics, metals and glass accounting for 3.9, 1.9 and 2.1% of the MSW, respectively (Gupta *et al.*, 1998). Average composition of municipal solid waste in Kolkata, India, during 2010 has been depicted in Fig. 4 (Das and Bhattacharyya, 2013).

As of 2018, almost 4.3 million tonnes of plastic MSW were generated on yearly basis in India (Ryberg *et al.*, 2018). Plastics, being derived from synthetic polymers, may get anaerobically decomposed in landfills, resulting in methane emissions. Source reduction is one of the best alternatives for reducing the quantity of waste generated, which can be achieved by

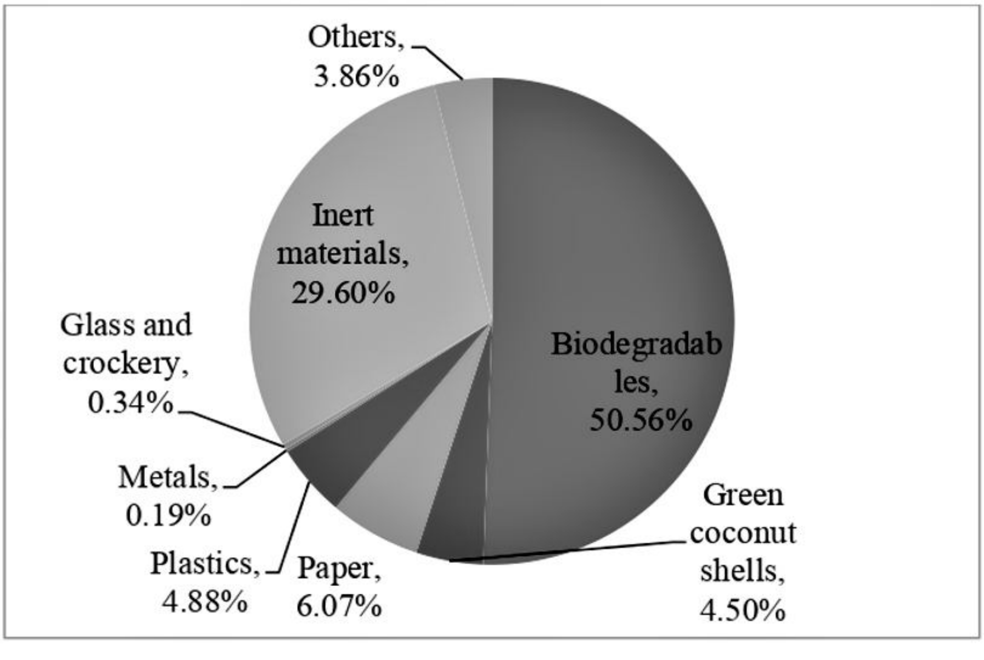

Fig. 4. Composition of municipal solids wastage in Kolkata, India, during 2010 (Source: Das and Bhattacharyya, 2013)

reducing or light weighting, reusing and recycling. Waste generation can be decreased by employing bulk delivery system or lowering the gauges of packaging materials. Marsh and Bugusu (2007) opined that by reducing the thickness of aluminium cans and paper board, almost 5.1 and 7.5 million pounds of aluminium and paper, respectively could be saved annually. Reusing of glass and cans, after proper washing with suitable detergents, also helps in reducing the wastage. The thermoplastic wastes can be reutilized by crushing and hot extruding it along with adhesives to manufacture plastic bottles (Briassoulis *et al*., 2013). Multi-layered plastics, which are difficult and uneconomical to recycle, can be used in the energy and chemical industry, construction material and textile industry and for manufacture of carbon nano-materials (Pan *et al*., 2020). India has already used plastic waste in development of more than 1 lakh kilometre of road, which not only possess superior strength, heat resistance and durability but also require less maintenance compared to ordinary bitumen roads (Trimbakwala, 2017; Pan *et al*., 2020). Apart from chemical and mechanical recycling, biological recycling is also gaining a lot of attention. Complete biodegradation of polystyrene by using mealworm larvae has been made possible in China (Yang *et al*., 2015).

Recycling of paper and paperboard not only reduces the carbon footprint considerably but also saves cutting of trees. To get the desirable strength, recycled paper should be blended with virgin paper at an appropriate ratio (Deshwal *et al*., 2019). However, such paper should not be put in direct contact with food to prevent migration of ink (if any) into the food. Paper and paperboard can also be converted into bioethanol, which is more cost-effective as compared to petrol (Wang *et al*., 2013). Incineration of plastic wastes (though not much eco-friendly) facilitates rapid waste disposal, emptying of landfills and can also be used to generate electricity (Idumah and Nwuzor, 2019). Online shopping produces almost 4.8 times higher packaging waste in comparison to offline packaging (Kim *et al*., 2022). The government and its regulatory agencies play a vital role in reducing packaging waste. According to plastic waste management rules (EPR-PWM, 2020), Government of India (GoI), it is the duty of the producer to collect and recycle the product under extended producers' responsibility clause (Pani and Pathak, 2021). Use and sale of non-recyclable multi-layered plastic has been banned under EPR-PWM (2020). Initiatives have also been taken by the GoI to phase out usage of single use plastics by 2022 (Pani and Pathak, 2021). Already, plastic carry bags having thickness below 50 micrometres has been banned. Nevertheless, proper implementation of these rules and regular inspection is a necessity for success of these efforts.

Green technologies in transportation of dairy products

Burning of fossil fuel during transportation of raw materials, feed, fodder, dairy products etc., emits GHG. Transportation accounts for about 24% of total carbon dioxide emissions world-wide due to fossil fuel combustion (Singh *et al*., 2019). It is the major GHG (96%) produced during transportation, followed by methane (3%) and nitrous oxide (1%) (Eide, 2002). Insulated trucks are preferred for milk and milk products, but transportation of frozen dairy products requires refrigeration, which again increases the carbon footprint. In food sector, transportation alone accounts for 5-50% of GHG production depending upon the products and processing system (Boye and Arcand, 2012).

Improvement in vehicle's efficiency, utilization of low-carbon fuels and proper logistic management are some of the ways to diminish GHG emissions from transport sector. A 10% reduction each in weight of the vehicle and aerodynamic drag can significantly enhance the fuel economy by 7 and 2%, respectively (Greene *et al*., 2010). Improvement in transport logistics, avoiding high-traffic roads, loading of vehicles up to its maximum capacity and reducing empty return trips etc. can significantly decrease GHG emissions. Driving the vehicle at prescribed speed, better shifting of gears and reduction in the number of start-stop of the vehicle can decrease fuel consumption by 7% (Mckinnon and Piecyk, 2009). Use of secondary, tertiary and quaternary packaging materials can help in transportation of more food products at a time. Pirog *et al.* (2001) noticed that local procurement of raw materials reduces GHG emissions. Use of bio-CNG, bio-diesel and hydrogen, instead of petrol and diesel, can again help in protecting the ecosystem through reduction in GHG emission (Negi and Mathew, 2018).

Conclusion

Milk and milk products play a crucial role in sustaining life of people. However, production of raw milk, processing of dairy products and their distribution significantly influence the environmental carbon footprint. Several LCA studies have been carried out to assess the impact of dairy sector on environment and to facilitate production of dairy products with low environmental carbon footprint. Adoption of green sustainable, energy-efficient and eco-friendly technologies in the dairy industry can reduce the adverse impacts in the form of depletion of natural resources, environmental pollution as well as human health hazards. Dairy industry has already adapted a few technologies to move a few steps in the right direction.

Conflict of interest: Authors have no conflict of interest in this study.

Author's contribution: PPD: Has written the portion on preservatives, water, packaging and transportation; KR: Has contributed matters related to novel green technologies, enzymes and by-products; AD: Has written the introduction, life cycle assessment and conclusion; MKS: Has written the abstract and is credited with conceptualization, compilation and editing the materials provided by the other authors. He is also responsible for submission and further actions necessary for publication of the article.

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