FOOD SCIENCE AND TECHNOLOGY

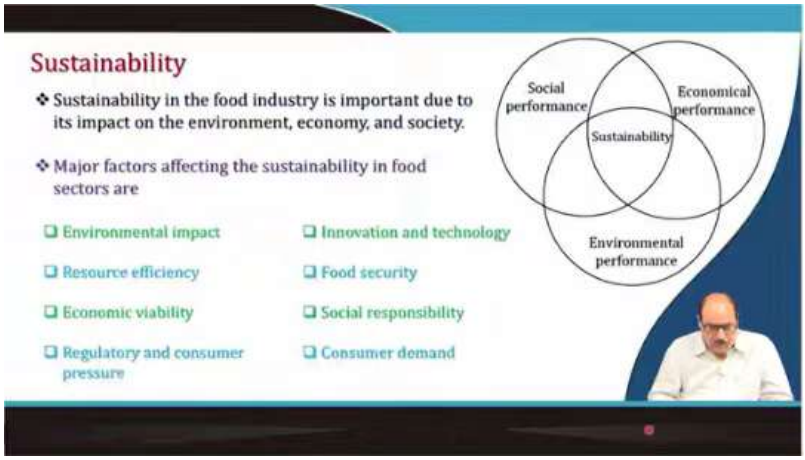
Lecture05

Lecture 5: Sustainability in Food Industry

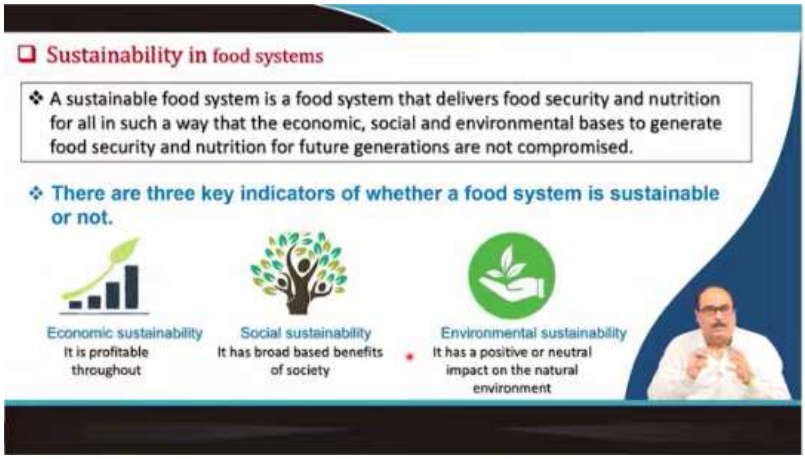
Hello everyone, Namaste.

Now, in the fifth lecture of module one, today we will talk about sustainability in the food industry.

We will discuss, in the next half an hour or so, what sustainability is and also what the current scenario of sustainability in the food industry is. What are the key drivers of sustainability? Prerequisites for achieving sustainability in the food industry and the various challenges in implementing sustainability. Also, we will talk about the role of consumers in food sustainability and technology and resource barriers.



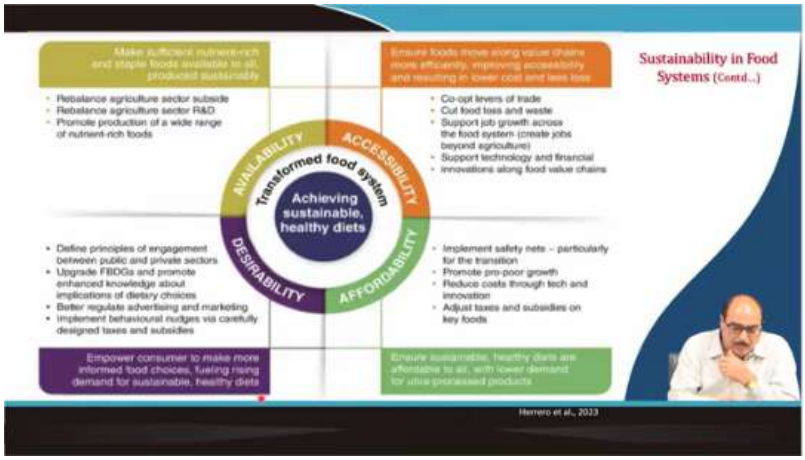
So, let us first see what sustainability is. In particular, sustainability in the food industry is important due to its impact on the environment, economy, and society. That is, sustainability when we talk about it, means that whatever the food system is—the food industry— it should have a role to play in social performance, economic performance, and environmental performance. So, the major factors that affect sustainability in the food sector are its impact on the environment, resource efficiency, economic viability, regulatory and consumer pressure, innovation and technology, food security, social responsibility, and finally, consumer demand. These are the various factors that must be considered in order to make a food system sustainable.



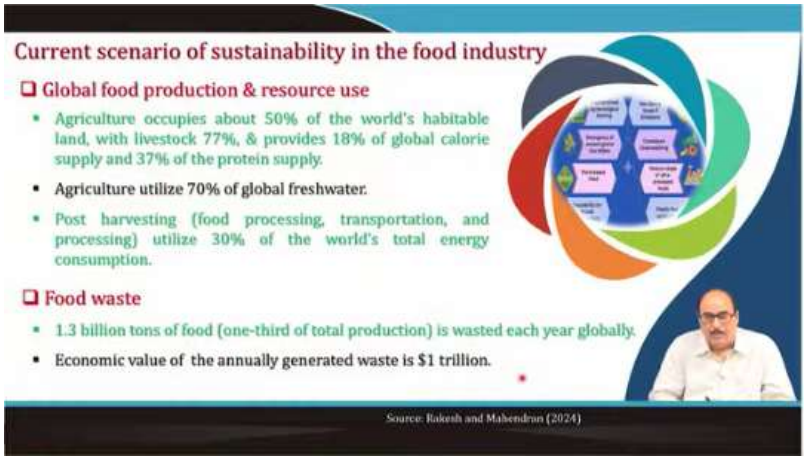
So, sustainability in the food system is one that delivers food security and nutrition for all in such a way that economic, social, and environmental bases are not compromised to generate food security and nutrition for future generations. That is the sustainable food system. There are three key indicators of whether a food system is sustainable or not. Number one is economic sustainability, that is, whether the food you are having, the food system, whether processing, everything, whether it is economically viable or not, whether

it is profitable throughout or not. Then, social sustainability means it is based on broad-based benefits for society. That is, the food will provide benefits to society. And then finally, environmental sustainability means it has a positive or neutral impact on the natural environment. So these are the major three key indicators of food sustainability.

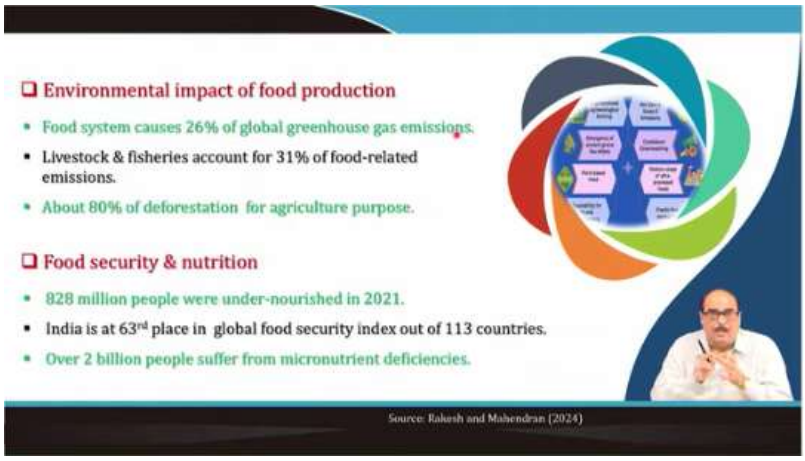
In sustainable food systems development, sustainability is examined holistically. In order to be sustainable, the development of the food system needs to generate positive value along three dimensions simultaneously. As I told you earlier, economic, social, and environmental. The economic dimension means food system activities must be commercially viable generating economic benefits such as wages, taxes, profits, and improved food supply for stakeholders. The social dimension means that sustainable food systems ensure equitable distribution of economic benefits considering vulnerable groups and contributing positively to nutrition, health, traditions, labor conditions, and animal welfare. The environmental dimension means that the activities of food systems should have a neutral or positive impact on the environment, focusing on biodiversity, water and soil health, animal and plant health, carbon and water footprints, and minimizing loss, waste, and toxicity.



So, achieving a sustainable healthy diet requires four factors. Availability, accessibility, affordability, and desirability. Availability means that sufficient nutrient-rich and staple food is available to all and it is produced sustainably. That is more important. That is, rebalance agricultural sector subsidies. Rebalance agricultural sector R&D. Promote the production of a wide range of nutrient-rich foods, etc. Then, accessibility, when we talk about it, means ensuring that food moves along value chains more efficiently. Improving accessibility results in lower costs and less loss. That means food becomes accessible to all. Co-opting levers of trade, cutting food loss and waste, supporting systems, and job growth are the various factors one should consider to make sure that food is accessible to all at cheaper and affordable prices. Then, affordability means ensuring sustainable, healthy diets are affordable to all. With lower demand for ultra-processed products. Finally, desirability means empowering consumers to make more informed and healthier food choices, fueling rising demand for sustainable, healthy diets, defining the principles of engagement between public and private sectors, upgrading FBDGs and promoting enhanced knowledge about the implications of dietary choices, better-regulating advertising and marketing, and implementing behavioural nudges via carefully designed taxes and subsidies. So, these are the four factors for achieving a sustainable, healthy diet.



So, what is the current scenario of sustainability in the food industry? Let us talk about the means, that is, global food production and resource use. You know, agriculture occupies about 50% of the world's habitable land, with livestock accounting for 77%. It also provides 18% of the global calorie supply and 37% of the protein supply. Agriculture utilizes 70% of the global freshwater. Post-harvesting, like food processing, transportation, and packaging, utilizes 30% of the world's total energy consumption. Then another is the waste. If you look at about 1.3 billion tons of food, which is one-third of total production globally, wasted each year. The economic value of the annually generated food waste is about 1 trillion dollars. So, you can see what such waste is—huge waste and huge economic wastage in terms of food loss.



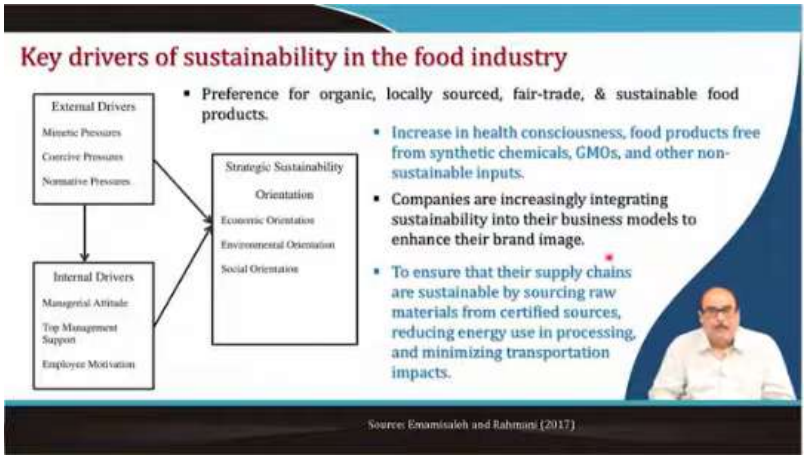
Also, let us see the present food industry or food system that exists and what its impact is on the environment—the environmental impact of food production. Even at present, the food system causes 26% of global greenhouse gas emissions. Livestock and fisheries account for 31% of food-related emissions. About 80% of deforestation, which also significantly contributes to greenhouse gas emissions, is for agricultural purposes. Then,

food security and nutrition. According to the data, about 828 million people were undernourished in 2021. India is in 63rd place in the global food security index out of 113 countries. Over 2 billion people suffer from micronutrient deficiencies globally. So you see, that is the major challenge to a sustainable food system.

Then, dietary patterns and consumer behaviour also, if you see—the plant-based food market is growing rapidly. Even the global market value is expected to reach $74.2 billion by the year 2027, according to the cited literature. Consumers are demanding sustainability—sustainably produced foods. That is, the consumer demand is increasing day by day. Then, sustainable practices were adopted. Organic farming covers approximately 75 million hectares worldwide, representing about 1.5% of the global agricultural land. So this has to be improved further.

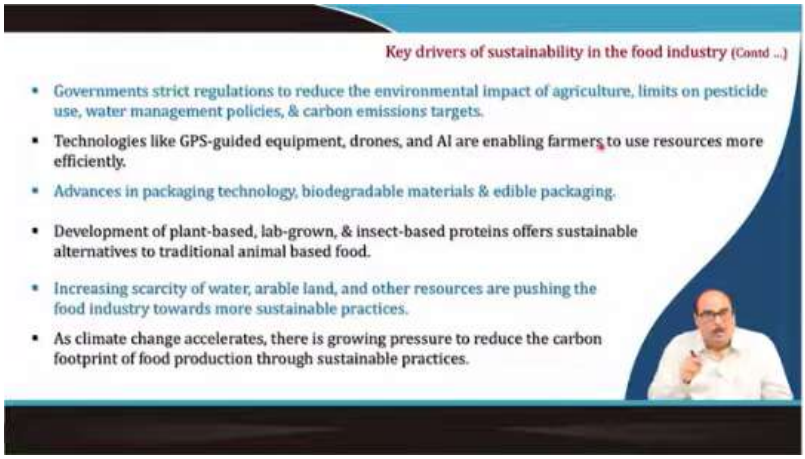
So, in this slide, I have just tried to show you the global greenhouse gas emissions from food production. The reference is already there; it is one, our World Data, which is the source. It is given in Statista. Then, you can see that global gas emissions, 52.3 billion tons

of carbon dioxide equivalent. In this, about 26% is from food sources, and about 74% is from non-food sources. The land use, like land use for human food, is 8% of the food emissions. Land use for livestock contributes 16% of food emissions, 24% is in the form of land use, that is, land use changes 18%, cultivated organic soil 4%, and savanna burning 2%. Then, during crop production, about 27% of the contribution is in greenhouse gas emissions. Like crops for animal feed, 6%. And crops for human food contribute around 21%. Then, livestock and fisheries contribute 31% to the greenhouse gas emissions. Livestock and fish farms contribute 30% of food emissions. Then, during the supply chain, the supply chain system contributes 18%, retail 3%, packaging 5%, transport 6%, and food processing around 4%. So that is the contribution of various sectors at present, the various sectors associated with food, their contribution to greenhouse gas emissions. In this slide, we have seen the enormous scale of global food wastage. That is the wastage—total food wastage per year in terms of tons. This is the red line, and this is yellow. It is estimated food waste per capita. So, you can see India and China followed by the US, Japan, and Germany. So, this is the decreasing order of annual food waste. China is on top. India is number 2, and then the USA comes in as far as total food waste is concerned. But if you look at the per capita waste, India comes comparatively lower. That is India, which weighs 50 kg per capita. per capita food waste is there. Whereas again, China is on the much higher side and the highest is in Australia, with about 102 kg of food waste per person. France is also equally very high, about 85 kg. But India, I think, in the data, is less, and Russia is the lowest, at 33 kg. So, you can see what the individual contribution is, alright?



So, the key drivers of sustainability in the food industry are three major factors: external drivers, strategic sustainability orientations, and internal drivers. External drivers are mimetic pressure, corrective pressure, and normative pressure. It puts pressure on internal drivers like management, real attitude, top management, support, employee motivation,

etc. and they all are interlinked in strategic orientation, economic orientation, environmental orientation, social orientation, etc. So, these are the key drivers. This means preferences for organic, locally sourced, fair trade and sustainable food products will be there. There is an increase in the health consciousness food products that are free from synthetic chemicals, such as GMOs, and other non-sustainable inputs. Companies are increasingly integrating sustainability into their business models to enhance their brand image. To ensure that their supply chains are sustainable, they should source raw materials from certified sources, reduce energy use in processing, and minimize transportation impacts.



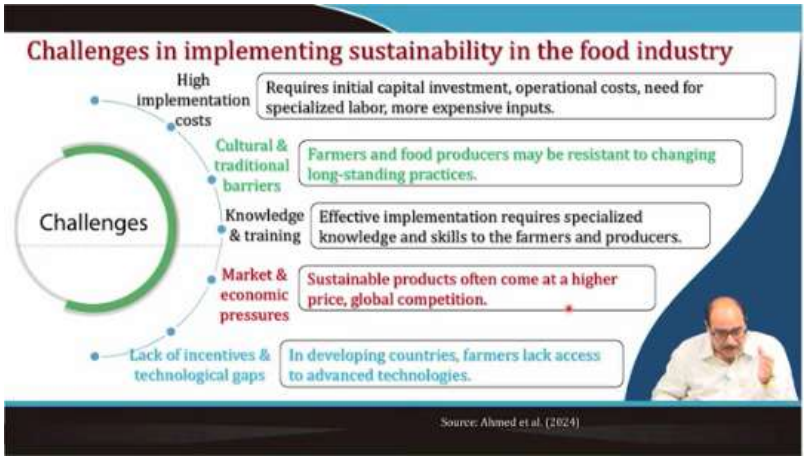
The government's strict regulations aim to reduce the environmental impact of the agriculture industry, limits on pesticide use, water management policies, and carbon emissions targets are also major drivers for sustainability in the food industry. Other technologies, such as GPS-guided equipment, drones, and AI, enable farmers to use resources more efficiently, which is a major boost to sustainability. Advances in packaging technologies, biodegradable materials, and edible packaging, along with the development of plant-based, lab-grown, and insect-based proteins, offer sustainable alternatives to traditional animal-based food systems. Increasing scarcity of water. Arable land and other resources are pushing the food industry toward more sustainable practices. As climate change accelerates, there is growing pressure to reduce the carbon footprint of food production through sustainable practices.

So, let's talk about the government initiatives for sustainability in the food system. Number one is India's National Action Plan on Climate Change, that is NAPCC, National Mission for Sustainable Agriculture, focusing on water conservation, efficient use of resources and climate-resilient farming techniques. That is the one major initiative of the government towards a sustainable food system or towards achieving sustainability in the food industry. Then, Starbucks coffee and farmer's equity practices. These improve product quality, promote environmental sustainability, and ensure fair labor practices. Then, impossible foods' plant-based meat, means innovative technologies to create plant-based meat products that mimic the taste and texture of animal meat. And finally, and more importantly, you can say the blockchain for food traceability by IBM Food Trust. It also uses blockchain technology to create a transparent, traceable, and sustainable food supply chain.

So, the solutions to overcome sustainability in the food industry are as follows: There are three major directions. Number one, more importantly, reducing food waste. In order to make a food system sustainable, one should try to work, as much as possible, to minimize

food waste, and that can be done by optimizing the supply chain. Even bringing awareness among consumers about food waste, etc. And then food recovery and redistribution. That is even when the food even from the shop markets, etc. That is company must take care that the food which is not sold. Then it should be taken back, recalled and then, where possible, it should be redistributed and re-given. Then another way is to promote sustainable diets that are based on alternative proteins and dietary pattern shifts. These are the ways by which one can promote sustainable diets and finally enhance supply chain sustainability, such as sustainable sourcing or reducing transport emissions. So, by proper management of all this, that is reducing food wastage, promoting sustainable diets, and enhancing supply chain sustainability by appropriate means. We can make that food environmentally safe, that is, it has less environmental impact. It provides good, proper nutrients in food to everyone, and so on.

The prerequisite for achieving sustainability in the food industry. Let us discuss this briefly. There are various prerequisites, as you can see here. As mentioned earlier, waste prevention is key. The most efficient production technology should be used. Then, internal recycling of production waste. Source-oriented improvement of waste and reuse of products or parts for the same purpose. As you see, prevention, preparing for reuse, recycling, recovery, and finally, disposal. So, these are the prerequisites, and we can take care of all these steps properly, like landfill installation, composting, industrial usage, feeding animals, feeding hungry people, and source reduction. By adopting these practices, one can ensure that food systems are sustainable.

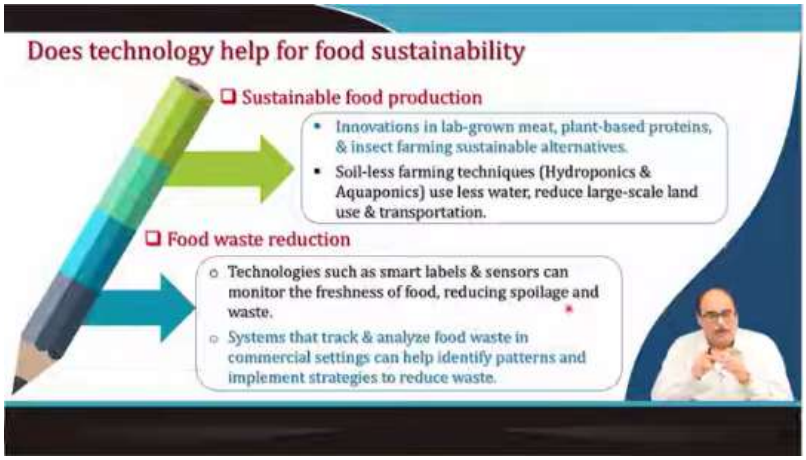


Now, let us talk about the challenges in implementing sustainability in the food industry. The first challenge is high implementation costs, such as food processing and production expenses. It requires establishing a good, sustainable food processing industry or food production systems. It requires a high initial capital investment, as well as operational costs. It needs specialized labor or more expensive inputs. The other challenge is cultural and traditional barriers. That is, farmers and food producers may be resistant to changing long-standing practices. That is the food we have been using traditionally and even the way in which the food is produced. It is processed in a way that may not be sustainable, but still, consumers normally do not like to change. Unless they are highly informed about the benefits, etc. So, many times, there is huge resistance—that is, cultural and traditional barriers exist. Knowledge and training are also very important factors. This is another major challenge: effective implementation requires specialized knowledge and skills for the farmers as well as producers. That is, they should all know the advantages—what is this food, which is part of a sustainable food system, etc., sustainable production, sustainable processing—what are the benefits of this? Why should they go for all such technologies? This should be done properly; that is, the knowledge dissemination, the farmers, even producers, etc., should be trained in these practices. Then, market and economic pressures like sustainable products often come at a higher price, and there might be global competition. Because of that, again, that is another challenge. So, one should work on this. That is, as far as possible, these products should be economical. Finally, there is lack of incentives and technological gaps. In developing countries, particularly, farmers lack access to advanced technologies and for having a sustainable food system, a sustainable food production system, the use of advanced technologies is very important. So, care should be taken that every effort should be made to make innovative technologies or novel technologies accessible to the farmers, producers, or processors, etc.

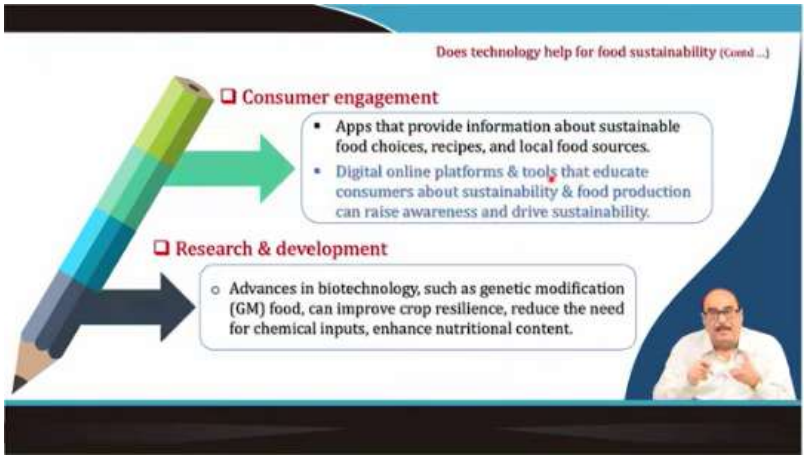
Then, even supply chain complexity. That is, ensuring all suppliers, processors, and distributors follow sustainable practices; monitoring from raw material to traceability throughout the supply chain is difficult, particularly in large-scale operations. But maybe using blockchain technology or other novel technology, it must be improved so that the product reaches and one should have a proper system to know where at a particular time, where the product is, what its quality is, whether it is good or not, all these things. So, in the supply, but obviously, the food is perishable items, and its supply chain is very complex. Then environmental and climate changes. Then unpredictable weather conditions perturb many times. Even extreme temperatures, soil fatality, and water scarcity make it difficult to implement sustainable agricultural practices. Many times, even trade regulations like international trade regulations can sometimes conflict with sustainable practices or social and cultural resistance, cultural and dietary preferences can make it challenging to promote sustainable diets. Finally, inadequate policy and regulatory support means weak enforcement and a lack of comprehensive policies that support sustainability in the food industry. So, these are some of the challenges in implementing sustainability in the food industry.

So, what is the consumer's role in food sustainability means choosing sustainable products, number one, like supporting sustainability by buying eco-friendly certified products such as organic and fair trade, and by prioritizing local and seasonal produce, reducing the carbon footprint associated with transportation. The other is reducing food waste, as consumers, as I told you, have a responsibility to plan meals, use leftovers, and understand food labels, such as 'use by' or 'best before'—all these practices, etc. Consumers can significantly reduce food waste and lower the environmental impact of food production and disposal. Because waste is minimized, obviously, environmental impact is minimized. Then, supporting sustainable brands, like consuming sustainable products and sustainably produced products and reducing their carbon footprint, encourages more businesses to adopt similar practices.

Then, advocating for change. Purchasing power to advocate for policies and practices that promote sustainability. Supporting legislative measures for environmental protection and participating in community initiatives. Educating. Consumers should try to educate themselves as well as others about the impact of food choices on the environment, etc. and support sustainable agriculture. Products with sustainable farming practices, reduced pesticide use, soil conservation, and water management. It all contributes to the health of ecosystems and biodiversity.

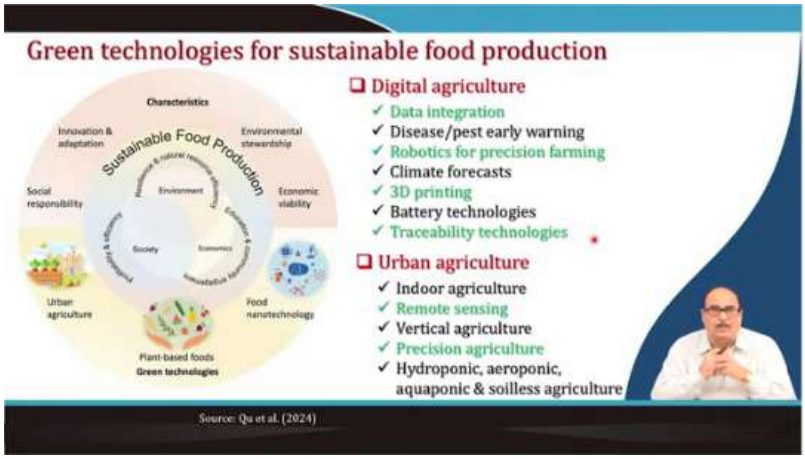


So, now let us talk about how technology helps with food sustainability. Get answers to these questions. Let us see. What are sustainable food production methods? Innovations in lab-grown meat, plant-based proteins, and insect farming are sustainable alternatives that are now emerging in a big way. Because of animals, it can prevent animal slaughter and also the rearing of animals for meat production. It is a highly costly process. Also, it creates a lot of environmental impacts and so on. Similarly, soilless farming technologies like hydroponics, aquaponics, etc. use less water, reduce large-scale land use and transportation, etc. So, these are the innovative technologies, obviously, which can aid sustainable food production. Then, food waste reduction means technologies such as smart labels and sensors can monitor the freshness of food, reducing spoilage and waste. Systems that track and analyze food waste in commercial settings can help identify patterns and implement strategies to reduce waste.

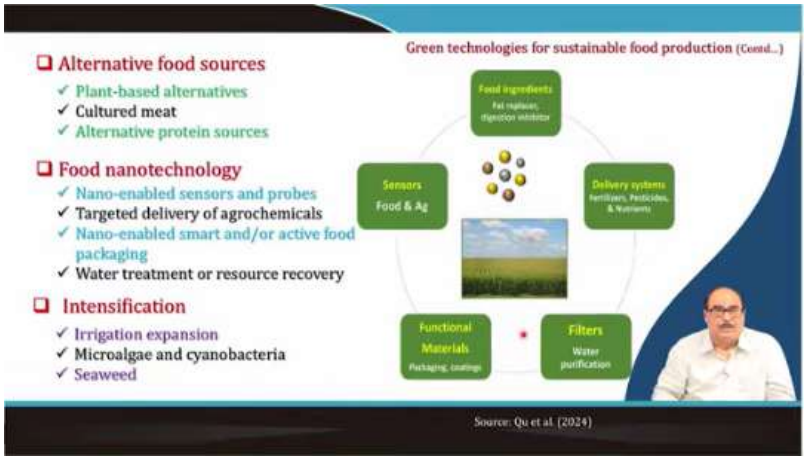


Then, consumer engagement apps that provide information about sustainable food choices, recipes, and local food sources. Digital online platforms and tools that educate consumers about sustainability and food production can raise awareness and drive sustainability.

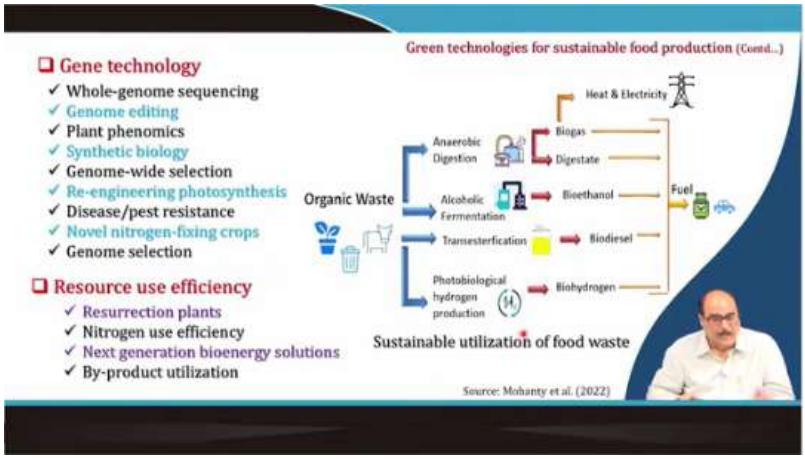
Nowadays, a lot of companies and even many startups etc. are working in these directions. And then, finally, research and development. Advances in biotechnology, such as genetic modification (GM) of food, can improve crop resilience, reduce the need for chemical inputs, enhance nutritional content, and so on. So, advancements, even in research, and more research and development should be done to develop better crop varieties that have more nutrients and better processing practices, and so on.



Green technologies for sustainable food production—obviously, that is, again, sustainable food production. Earlier, we also discussed that the environment should be resilient and natural resource efficiency, should include education and community engagement in economics and society. That is profitability and efficiency. So various technologies like food nanotechnology, plant-based food, green technologies, urban agriculture, social responsibility, innovation and adaptation, environmental stewardship, and economic viability—are the different characteristics of sustainable food production. And you can say, if you see digital agriculture or urban agriculture, in digital agriculture, data integration. Disease and pest early warning systems, even robotics for precision farming, etc. Now, we use climate forecasts and 3D printing technologies for formulation, food processing, etc. Battery technology or traceability technology- all these things are now digital in agriculture, in digital agriculture, and in digital processing- are becoming very, very important now. Then urban agriculture, like indoor agriculture, remote sensing, vertical agriculture, precision agriculture, hydroponic, aeroponic, aquaponic, and soilless agriculture, etc. Vertical farming and all those things are now coming in a big way, even in cities. People are now working on rooftops and doing soilless agriculture.

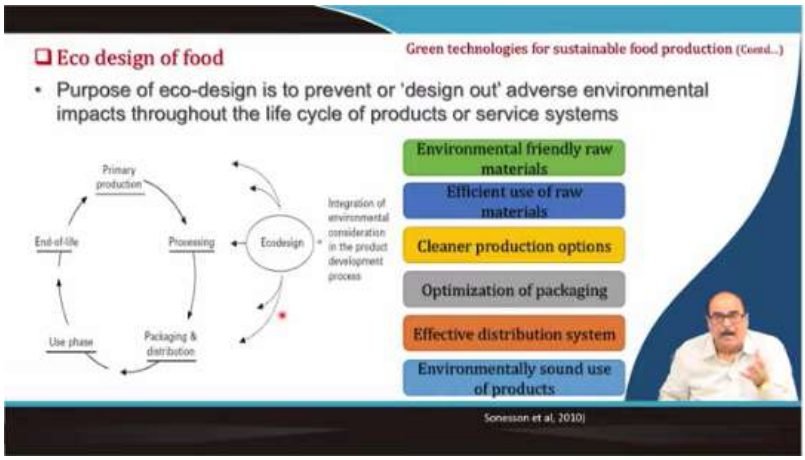


Then alternative food sources, like plant-based alternatives, cultured meat, alternative protein sources, etc. There are various. Then, food nanotechnology means nano-enabled sensors and probes, targeted delivery of agrochemicals, nano-enabled smart or active food packaging, or water treatment for resource recovery, all of which are done by using nanotechnology. These various sensors and devices can be developed, which becomes a major boost for sustainable food production. And then intensification, like irrigation expansion, microalgae and cyanobacteria, other seaweeds, etc., as they can be alternate sources of proteins and other things. This can be used.



Gene technology includes whole genome sequencing, genome editing, synthetic biology, genome-wide selection, re-engineering photosynthesis, disease or pest-resistant varieties, novel nitrogen-fixing crops, or genome selection. Why? This means that by genetic engineering and gene technology, one can have resistant or improved varieties and improve them from all things like disease and pest resistance variety and other things. Then, resource use efficiency, particularly resurgent plants, nitrogen use efficiency, next-generation bioenergy solutions or by-product utilization, etc., are all those things. So, here,

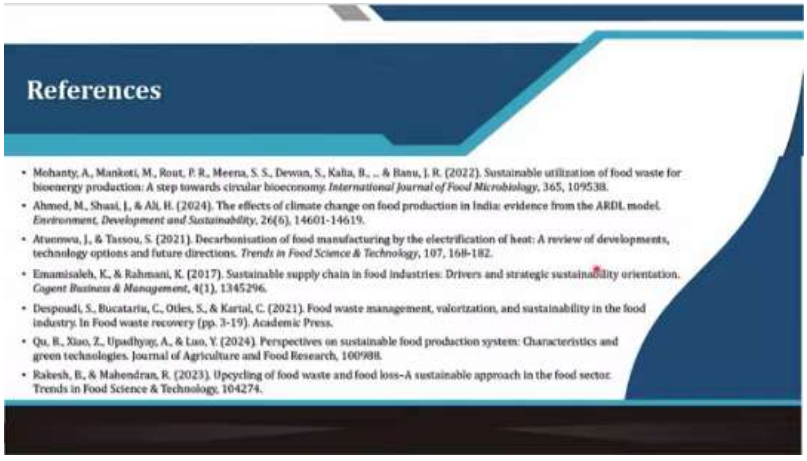
it means that there is sustainable utilization of food waste if you take it, like organic waste, okay? They can be used for anaerobic digestion or alcoholic fermentation or even transesterification, photobiological hydrogen production. So, these can be segregated and accordingly used by various technologies like even anaerobic digestion, that is biogas and digestate, that is, this can be produced. It can be used for heat and electricity and then bioethanol, biodiesel, biohydrogen—it is the fuel production, etc. So, these are various ways, that is, there should be a proper collection system for the food waste and these collection systems can be segregated into organic and inorganic waste and the organic system again, they can be Like, even you see that in the food processing industry, after the extraction of juice, there is the residue which is left. They contain a lot of bioactive ingredients, antioxidants, and all those things. They can be properly channelized through proper extraction technologies and other things.



Then, finally, eco-design of food. That is the purpose of eco-design. Is to prevent or design out adverse environmental impacts throughout the life cycle of the products or services or systems. So, here, one has to integrate environmental considerations. In the product development process. That is what eco-design means, and how is it done? That is why you say all this. Primary production, processing, packaging and distribution, use phase and then finally in life. All these things have to be considered. Environmental considerations should be properly integrated into product development and process. Means that is environmentally friendly. Raw material use: efficient use of raw materials, cleaner production options, optimization of packaging, effective distribution systems, and environmentally sound practices. These are some of the measures one should take in food processing and packaging, and therefore, one can develop a sustainable food product, a sustainable food system, that has fewer adverse effects on the environment. It is

economical, cheaply available, and consumer-friendly, and it is liked by consumers, access, etc.

Finally, I would like to summarize this lecture by saying that sustainability in the food industry is important due to its impact on the environment, economy, and society. The global food system causes 26% of greenhouse gas emissions, with $1 trillion in waste, high costs, lack of access to advanced technologies, and cultural resistance as significant barriers to achieving sustainability in the food industry. Technologies like artificial intelligence, drones, and biodegradable packaging, along with advances in plant-based and lab-grown foods, etc. They are supporting sustainable practices. Consumers can support sustainability by choosing eco-friendly products, reducing food waste, and advocating for policy changes.



These are the references I have used in this lecture.

Thank you very much for being here. Thank you.