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Current and future applications of food science and technology to feed the world's population

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Abstract
Earth's ability to produce new resources decreases as the world's population grows. As bioresources deplete, new approaches are needed to feed current and future populations. In recent decades, food production has improved, fresh ingredients have been discovered, and new food structures have been designed and built. This review uses cellular agriculture, microalgae, insects, and wood-based fibres as examples of new food or ingredients. It will also take a quick look at the entire food design process, from brainstorming new food concepts to applying artificial intelligence, augmented reality, and blockchain technology to the industry. Need to see how covid -19 affects the food supply chain. Food science and technology have made significant advances in recent years, and this review was written to provide an overview of these developments for a variety of viewers. This article discusses innovative ideas for global food security over the next 2 to 3 decades.

Keywords: Food security, food production, food design, circular economy, human population, food waste

Introduction
The Earth's ability to produce its resources is dwindling as the human population grows at an accelerating rate (Ehrlich and Holdren, 1971; Henderson and Loreau, 2018) [28, 51]. There has been a intensely increase in the world's population over the past half-century. The earth overun day, which will occure when mankind will depletes the planets early removable bioresourses is moving closer and closer.

As a result of the recent coronavirus pandemic (Global Footprint Network, 2020a) [38], Earth's overshoot date has been pushed back to August 22, 2020. It's not because of any long-term strategy but rather of a pandemic disease. To improve the sustainability of our society, this is still necessary and entities need to consume bioresources. Just 26% of our ecological footprint is due to food production and waste; that's not the whole picture (Global Footprint Network, 2020b) [39]. This is due to inefficient food production and poor waste management. It is possible to delay the Earth's overshoot day by encouraging more sustainable behaviour throughout the food chain and in the home. As a result, the Earth's regenerative capacity would be preserved (Moore *et al*., 2012) [82]. A projected 9.7 billion people will populate the world by 2050. The most important thing is to make sure that everyone has enough food to eat.

When it comes to ensuring everyone has enough food, reducing waste and food loss is an integral part of the equation. The Food and Agriculture Organization (FAO) estimates that about 1.3 billion tonnes of food are lost or wasted in the food chain from production to retail and by consumers. In light of this, consumer education and the circular economy are critically important. If economic barriers can be eliminated, low-income people will be able to access better and more sustainable food. However, reducing waste and removing financial obstacles will not be sufficient to improve the food quality available to the world's population. Indeed, to feed the world's population in 2050, food production must increase by 70%.

Floros *et al*. studied that, people should eat more plant, insect, and microalgae-based foods in their diets to combat the effects of climate change (van Huis and Oonincx, 2017; Caporgno and Mathys, 2018; Lynch *et al*., 2018) [132, 16, 72].

It's time to switch to a plant-based diet because animal-based diets deplete our natural resources faster and wreak environmental devastation (Sabaté and Soret, 2014) [116]. As of course its not easy to get people to change how they prepare and consume food. To be effective, the methods must be cost-effective, sustainable, and environmentally friendly. For new food products to gain cultural and social acceptance, economic accessibility, and a taste that people enjoy, they must contain adequate nutrition. In addition, fresh foods should aim to maintain or improve the health of those who consume them. To address these issues, advances in food science and technology can be used to enhance food production, add new ingredients sourced from more environmentally friendly sources, and create new, consumer-pleasing food products. However, there are numerous advantages to consuming food that has undergone technological advancements. To have an impact on people, products alone are not enough. People's attitudes toward food and how much of it they desire vary widely. Things like geography and society, for example, play a role in shaping the world we live in. The structure, economy, personal income, religious constraints, and other technology can be used today. Food that is both safe and nutrient-dense. Food is the best source in the terms of macronutrients and micronutrients. This is essential for people in low-income countries (Sasson 2012; Bain *et al*., 2012) [120, 146]. 2013 saw an increase in the importance of health in medium- and high-income countries. Nutritional foods that can help you avoid developing long-term health problems Azais-Braesco *et al*. (2009) [6] describe green food as Chingwaru and Govindaraj have also discussed this. Because of the sheer number of nutrients required to sustain life, our conceptions of food have evolved over time for daily living (Floros *et al*., 2010) [32] to prevent nutrition-related diseases (e.g., non-communicable) from occurring, to enhance human health and well-being, and to slow or stop the ageing process (Siró *et al.*, 2008) [123], diabetes, heart disease, cancer, and obesity are some of the conditions people used get (Rockenfeller and Madeo, 2008) [147]. This could be a reason that the new food items should be developed and for this need to consider what coustomer wants and whats their needs. Even though there are times when money can make it more challenging to travel. There must be a sufficient supply of food and new and improved food-a group of people who purchase products that include additional benefits.

Food Science and Technology Solutions for Global Food Security

The Circular Economy is an economic model based on reusing and recycling resources. It is time to abandon the unsustainable practice of taking, making, and discarding materials in a linear (take, make, dispose of) economic model (Jrgensen and Pedersen, 2018) [56]. An infinite supply of raw materials is no longer seen as a problem in a circular economy. Closing the supply chain's loop of materials and substances is how they manufacture their products. To keep the economy from losing money, this model keeps the value of goods, materials, and resources in the economy for as long as possible (Merli *et al.,* 2018) [78]. They reduce waste and food loss, maximize natural resources, and protect biodiversity benefit the circular economy (Jurgilevich *et al.,* 2016) [58]. This is accomplished by cyclically utilizing resources, thus reducing the demand for new raw materials in the food production process. Dudley and Alexander (2017) [27] stated that the efficient use of natural resources for food in a circular economy helps rebuild biodiversity. It prevents more of these resources from being used for food production.

This measure is essential because a lot of waste is made at different points in the food supply chain. Thirty percent of the food grown for human consumption is lost or wasted, which costs the world's economy about $1 trillion a year (FAO, 2019) [30]. Food loss and waste also impact the environment because of the greenhouse gases released when food waste is put in landfills and when food is grown, processed, manufactured, transported, stored, refrigerated, and sold (Papargyropoulou *et al*., 2014) [95]. Greenhouse gases are released when food is wasted or lost. This is made worse when there is a lot of wasted food in the food supply chain. When it comes to reducing food loss and waste, it is essential to know what food loss and destruction are. It's a problem with how much or how good the food is that causes food loss and waste, according to the FAO (FAO, 2019) [30]. From the time a food is grown to when it is harwasted there is a lot of food that isn't used. On the other hand, food waste happens at the store or restarant, when people buy and eat it and spare food dump in a dusbin or keep as such. For example, when food is used for other things, like animal feed, it isn't wasted or lost if used for something else and otherhand inedible parts of food like bones, feathers, and peel aren't wasted (Xie *et al*., 2021) [140].

It's called the Waste and Resources Action Programme (Quested and Johnson, 2009) [106], and it's a charity in the UK. They say that food waste can be both avoidable and unavoidable. For example, some vegetables and fruits don't meet specific standards, so they were thrown away. Leftovers, damaged stock, and food that was not used are examples of food that could be used. During food preparation or production, there is a lot of waste that can't be avoided. This waste includes things that aren't ordinarily edible, like vegetable and fruit peels, bones, fat, and feathers. As long as there isn't agreement on what food loss and waste are, the less food that is lost or wasted is going in one direction: make sure that there is enough food for everyone on Earth. The best way to cut down on wasted food is to prevent it from happening in the first place. This can be done at all stages of the food supply chain. Making sure there isn't too much food to go around, improving packaging and storage facilities, and educating people about how to plan their meals, understand best-before dates, and buy food that may not meet quality standards because it looks good are some ways to cut down on waste (Papargyropoulou *et al*., 2014) [95]. To cut down on food waste that can't be avoided, side-stream products can be used as raw materials to make new food or non-food products, which can then be sold.

It's possible to compost both food waste that can be avoided and food waste that is unavoidable to grow more food (Jurgilevich *et al.*, 2016) [58]. There should be no waste at all in a circular food system, as it is used as a feedstock for another cycle, creating a system that appears to be self-sustaining and organic (Ellen MacArthur Foundation, 2019) [29]. Food waste, which comes mainly from food processing industries, is being used to develop new food technologies that maximize the value of food waste. Thanks to these new food technologies, food waste can be transformed into new food ingredients or materials that can be used for various other purposes (Ohlan, and Ohlan, 2022) [90].

Whey, the liquid leftover after making cheese and paneer, is an example of side-stream valorization. It is terrible for the environment if it is thrown away untreated. More than 35,000 ppm BOD and more than 60,000 ppm COD make it one of the most toxic environments (Smithers, 2008) [124]. The high BOD and COD values can harm aquatic life if the untreated whey is thrown away, and as a result of this dissolved oxygen levels in the water are reduced.

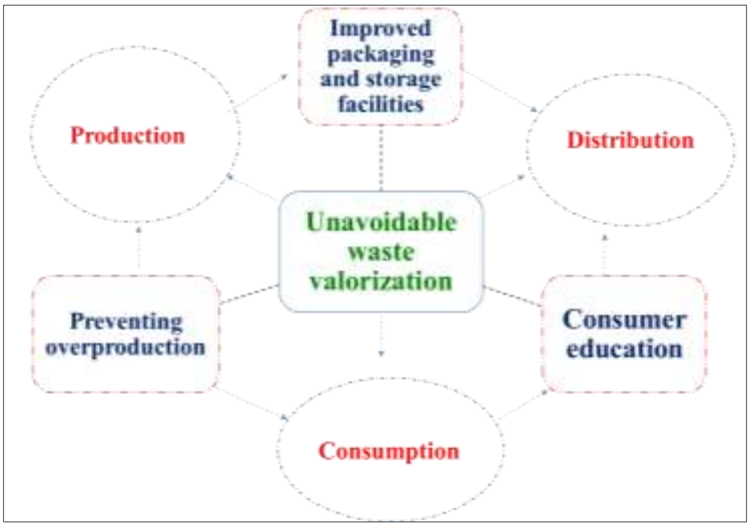

Fig 1: Food waste reduction strategies in the food supply chain in a circular food system

Cheesemakers used to send their whey to be used as pig feed because it is rich in lactose and proteins, and this practice continues today in some parts of the country. Lactose and whey protein were discovered to have significant nutritional and technological value as dairy science advanced. In infant formula or as a source of glucose and galactose for making glucose and galactose, lactose can be separated using various methods (Smithers, 2008; de Souza *et al.*, 2010) [124, 23]. Also popular as a sports nutrition supplement and a way to enhance the functional properties of food, whey protein is gaining in popularity. Increased consumption of isolate and concentrate products has resulted from this (Lagrange *et al.*, 2015) [68]. Different products are produced by byproduct of the meat-processing industry that can be used to make main food meal. Centrifugation can easily separate the plasma fraction of animal blood, which contains a variety of plasma proteins. Like whey proteins, some of these proteins can aid in the stability of colloidal food systems.

Table 1: Industrial by product and its possible use in human diet

Industry	Valorizable compound	Possible use	References
Plant based food production	Maize nixtamalization wastewater	Carbohydrates and polyphenol	
	Discarded cereal, fruit, and vegetables	Feedstock for food pigment production gelling agents	Castro-Munoz and Yanez Fernandez, 2015 [17]
	Potato peel and potato fruit juce	Carotenoids, flavonoids, phenolics, and other secondary metabolites Protein and polyphenol extracts	Gutierrez-Uribe *et al.*, 2010 [47] Panesar *et al.*, 2015 [94] Plazzotta *et al.*, 2017 [102] Rahmanian *et al.*, 2014 [108], Plazzotta *et al.*, 2017 [102] Saini *et al.*, 2019 [117] Fritsch *et al.*, 2017 [34]
Cheese production	Whey	Lactose for infant formula Whey protein as food additive and emulsifier	Smithers, 2008 [124], de souza *et al.*, 2010 [23] Lagrange *et al.*, 2015 [68]
Seafood processing	Fish skin and bones	Alternative gelatin source Chitosan for packaging materials	Karayannakidis and zotos, 2016 [63] Kandra *et al.*, 2012 [62]
	Liquid side-stream	Astaxanthin for food pigment Polyunsaturated omega-3 fatty acids	Kandra *et al.*, 2012 [62] Monteiro *et al.*, 2018 [81]
Meat processing	Skin, bones, and connective tissues	Gelatine and umami peptides	Toldra *et al.*, 2012 [129]
	Fibrinogen and thrombin	Meat glue for restructure meat product	Toldra *et al.*, 2012 [129]
	Blood plasma proteins	Emulsifier	Toldra *et al.*, 2012 [129]

Fibrinogen and thrombin, for example, can be used as meat glue to create restructured meat products. The skin, bones, and connective tissues of dead animals can be used to make gelatin, which is an important gelling agent. It is possible to create short peptides with an umami flavor. Non-muscle tissue from farm animals, particularly cows, would be tough to obtain to be safe. Before this could happen, toxicology tests would have to be carried out. In addition, non-meat tissues can be contaminated with prion proteins, which cause a deadly disease when consumed (Toldrá *et al.*, 2012) [129]. People who consume non-meat products may be at risk for this. The seafood industry's by-products are also a great source of revenue, as there are many well-known products and many more yet to be discovered. Gelatin made from fish skin and bones may be an option for those who are unwilling or unable to consume cow or pig gelatin (Karayannakidis and Zotos, 2016) [63]. Carotenoid and chitin can be extracted from the shells of joint seafood like crab or lobster. Chitosan, a well-known biopolymer that could be used to package food, can be made from chitin from shells. Another option is to recover the shells carotenoids, such as astaxanthin, for further use. It can be used as a nutritious food supplement (Kandra *et al.*, 2012) [62].

The liquid produced during the fish-canning process has a lot of potentials. This liquid contain bioactive lipids such as polyunsaturated omega-3 fatty acids (Monteiro *et al*., 2018) [81]. To meet the needs of both vegetarians and vegans, plant-based functional ingredients can be produced from plant food processing side streams. For example, the wastewater produced by the alkaline processing of maize, known as nixtamalization, contains a high concentration of carbohydrates and polyphenols, but it is also highly alkaline. Because nixtamalization raises the alkalinity of the maize, this is the concern. Microfiltration and ultrafiltration are used to separate the nixtamalization wastewater's carbohydrate and polyphenol enriched fractions (Castro-Muoz and YáezFernández, 2015) [17]. Microbial fermentation of waste from the cereal, fruit, and vegetable industries can also be used to produce food coloring (Panesar *et al.*, 2015) [94]. Leafy vegetables and fruits that are not good enough to be sold to the customer that can also be used for pigment extraction in the industry. Bioactive compounds and natural gelling agents both can be derived from waste. Food that tastes better and is better for you can also be made from this waste (Plazzotta *et al*., 2017) [102]. Using green technology, carotenoids, flavonoids, and phenolic compounds can be extracted from fruit and vegetable waste and wastewater from an olive mill. Ultrasound, microwave pulses, pulsed electric fields, enzymatic techniques, and membrane techniques are among the technologies that can be used to create supercritical CO_2 (Rahmanian *et al*., 2014; Saini *et al*., 2019) [108, 117].

Alternative methods and relative sources of food production

Using potato peel and juice as a source, this strategy can also produce a variety of polyphenols and alkaloid derivatives, as well as protein extracts (Fritsch *et al*., 2017) [34]. Wasted food can also be used to make food, but it is not the only option. The extraction of emulsifiers from sawdust, for example, can demonstrate how waste from one industrial cycle can be used as a feedstock for another industrial cycle and thus reduce the amount of waste in the process. A significant amount of straw is generated during the cultivation of grains. The oligosaccharides that can be extracted from this straw can be used in various food products (Huang *et al*., 2017; Alvarez *et al*., 2020) [54, 3]. The polyphenolic antioxidants found in older bamboo leaves can boost the nutritional value of food when used in Asian dishes that typically call for young bamboo shoots. Bioactive compounds can be incorporated into the product using older bamboo leaves (Ni *et al*., 2012; Nirmala *et al*., 2018) [84, 87]. More food must be produced to feed the ever-growing population, and the circular economy concept must be used in conjunction with it. Resources like water and land have been depleted while the climate has shifted. As a result, food production has become more complex. Climate change is expected to cause a 3.2 percent decrease in the global food supply. A wide variety of foods, including fruits, vegetables and red meat, are involved (Springmann *et al*., 2016) [125]. For example, two strategies are being used to improve agricultural productivity and resource use: vertical farming and genetic modification. These two methods also increase and/or modify the nutritional value of food and produce new alternatives to food and/or food ingredients. They also protect biodiversity. It is possible to increase food production in your area by using fewer resources and making the most efficient land use through cellular agriculture. There are many types of protein, fat, and fiber-rich food products that can be made using cellular agriculture. If people wants to avoid using animals, two other options are tissue engineering and fermentation (Stephens *et al*., 2018) [126]. Muscles that can be eaten as food are created by using cells from living animals in the tissue engineering process.

This is accomplished through the use of mechanical and enzymatic methods. In the case of fermentation, organic molecules are produced without animal cells. Instead, organic molecules are synthesized by bacteria, algae, and yeast that have been genetically modified. Soleil, a single-cell pure protein manufactured by Solar Foods, is made through the fermentation process. Microorganisms are fed with air-derived nutrients (hydrogen (H), oxygen (O), & carbon (C)), vitamins, and carbon dioxide (CO_2) during this bioprocess. The protein is then processed into a powder that can be used in food. Cell farming has focused on animal products like beef, chicken, fish, lobster, and protein for making milk and eggs (Post, 2014; Stephens *et al*., 2018) [103, 126].

As a source of protein, fat, polysaccharides (like chitin), fiber, vitamins, and minerals, insects may turn out to be an excellent choice. Edible insects can be consumed in various forms, including raw or cooked. It's the case in Asia, Central and South America, Africa, and the Mediterranean (Duda *et al*., 2019; MelgarLalanne *et al*., 2019) [26, 77]. Edible insect production is a highly efficient process. Like vertical systems, it generates a steady stream of new generations of insects throughout the year with a low mortality rate (Ramos-Elorduy, 2009) [109]. A further advantage of growing edible insects is the low cost of the materials used, many of which can be found right where the insects are being grown. Insects can indeed feed on human food waste and agricultural waste. It is possible to incorporate insects into the diet to make it more environmentally friendly and more diverse food. There is still a lot of resistance from people who don't like eating bugs, so that obstacle must be overcome (La Barbera *et al*., 2018) [67]. People can get used to eating insects more easily if they use flour or powdered insects (Duda *et al.*, 2019; Melgar-Lalanne *et al*., 2019) [26, 77]. Insect biomass can be converted into food ingredients in various ways, including freezing, oven drying, fluidized bed drying, microwave drying, and more (MelgarLalanne *et al*., 2019) [77]. These include techniques like ultrasound-assisted extraction, cold atmospheric pressure plasma, and dry fractionation. Cricket powder has recently been used to supplement pasta's protein, fat, and mineral content. This enhanced the pasta's nutritional value and its appearance and feel (Duda *et al*., 2019) [26]. Chitin, the outer shell of insects, can be used to make bioactive products like chitosan. Disease prevention and treatment could benefit from these products (Azuma *et al*., 2015; Kerch, 2015) [7, 65]. Insects may be an excellent source of protein, fat, polysaccharides (like chitin), fibre, vitamins, and minerals. Edible insects can be consumed in various forms, including raw or cooked. In Africa, Central and South America, and Asia, this is the case (Duda *et al*., 2019; MelgarLalanne *et al*., 2019) [26, 77]. Edible insect production is a highly efficient process. Like vertical systems, it generates a steady stream of new generations of insects throughout the year with a low mortality rate (Ramos-Elorduy, 2009) [109]. A further advantage of growing edible insects is the low cost of the materials used, many of which can be found right where the insects are being grown. Insects can indeed feed on human food waste and agricultural waste. The circular bioeconomy paradigms that have been proposed are in line with this. It is possible to incorporate insects into the diet to make it more environmentally friendly and more diverse. Disease prevention and treatment could benefit from these products (Azuma *et al*., 2015; Kerch, 2015) [7, 65]. Emulsifier applications for regenerated chitin include stabilizing yogurt, creams, ice cream, and more (Xiao *et al*., 2018) [139]. Insect-based food products such as whole insects, powder, and other ingredients have already been sold worldwide. Some examples of these include flavor-infused snacks, energy bars, shakes, and candy. There is still a need for food processing and technology to help people overcome their fear of new foods and satisfy their taste preferences (Melgar-Lalanne *et al*., 2019) [77]. Asian countries, according to Priyadarshani and Rath (2012) [105], can obtain nutrients from algae and microalgae. Whole food or an extract can be consumed. The extracts contain biomolecules that plants cannot produce as quickly as those found in the extracts (Torres-Tiji *et al*., 2020) [130]. Algae and microalgae can be improved by selecting the right genotype, changing or improving it, and controlling the growing conditions (Torres-Tiji *et al*., 2020) [130]. In the past, algae and microalgae have been consumed directly, such as nori in sushi. It's become increasingly popular to prepare functional foods by extracting bioactive compounds from algae and microalgae. Spirulina and chlorella are here to help. These two microalgae species have been approved for use in food by the European Union (Zarbà *et al*., 2020) [145]. These microalgae include proteins, fatty acids, glucan, vitamins, minerals, antioxidants, and pigments. They're also high in phycocyanin, a blue-green alga with many nutrients (Priyadarshani and Rath, 2012; Vigani *et al*., 2015; Wells *et al*., 2017; Sathasivam *et al*., 2019) [105, 133, 136, 121]. The other molecules can be recovered using a pulsed electric field, ultrasound, microwaves, and supercritical CO2 (Kadam *et al*., 2013; Buchmann *et al*., 2018) [59, 14]. In addition to digestible proteins, lipids, and carbohydrates, dietary fiber is also critical. Insoluble (polysaccharides and lignin) and soluble (pectin and hydrocolloids) make up dietary fibers. Fruits, vegetables, cereals, and grains consumed immediately are the most common sources (Medendorp *et al.*, 2022; Liu *et al.*, 2020; McKee and Latner, 2000) [75, 70, 74]. While the right amount of fiber can have numerous health benefits, the rise of low-fiber foods in Western countries has decreased fiber intake (McKee and Latner, 2000; Anderson *et al*., 2009) [74, 4]. Fiber supplements were developed due to a deficiency in the diet (McKee and Latner, 2000; Doyon and Labrecque, 2008) [74, 25]. Aside from contributing to overall health and well-being, dietary fibers also enhance the appearance and texture of food (Sakagami *et al*., 2010; Tolba *et al*., 2011; Jones, 2014; Aura and Lille, 2016) [118, 128, 55, 5]. Wheat, corn, oats, sorghum, orange peel, pineapple shells, and more are all sources of dietary fiber (Pitkänen *et al*. 2018) [100]. In the context of a circular economy, it makes sense to use plant derivatives and waste in this way. This contributes to a more sustainable food chain. The relevant regulatory systems must approve new and alternative food and ingredients sources before they can be sold. This is a critical point to keep in mind new food regulations are used in Europe to ensure the safety of new foods, Regulation (EU) 2015/2283 is the name of these rules (Mok and Chen, 2020) [80]. Toxicology, composition, stability, allergies, and other factors must be considered when a new food or food ingredient is created or added to a food or food and also the regulations like to ensure that new foods and food ingredients are safe for consumption by the general public (Barrett, 2021) [8].

Fig 2: Visions for the future of food based on current possibilities for maximising the use of better techniques, sources of food and nutrient ingredients

Food design

Food design is the art of making the food to look good. Humans are at the heart of the food supply ecosystem, and they have a wide range of changing A vision of the future of food based on existing possibilities for maximising the use of novel techniques, food sources, and nutritional ingredients. expectations. To make food more sustainable by using new materials and technologies discussed in the previous chapters, the framework for food production and consumption should go beyond making edible objects and include the creativity to change people's neophobia and make them more willing to try new things. These new ideas should also consider changes in consumer demographics, lifestyles, and nutritional needs. Food design is a new field that tries to make the food value chain more human-centered by using a design thinking process at every step, from making the food to throwing it away (Olsen, 2015; Zampollo, 2020) [92, 144]. Food product design is a A vision of the future of food based on existing possibilities for maximising the use of novel techniques, food sources, and nutritional ingredients. Subdiscipline of food product design that deals with how to choose food products from a technological point of view.

Making food look good is a skill in food design, an art form. There is an ever-changing range of expectations from humans in the food supply ecosystem. Instead of focusing solely on creating edible items to satisfy people's neophobia and increase their willingness to try new things, the food production and consumption framework should incorporate the creativity discussed in the preceding chapters to make food more sustainable. New concepts should also consider the shifting demographics, habits, and dietary requirements of today's consumers. In the food design field, a design thinking process is used at every step, from making the food to throwing it away to making the food value chain more human-centered (Olsen, 2015) [92]. Designing food products from a technological perspective is a subdiscipline of product design that deals with how to select food products.

The current conventional approach to mass production of food must be replaced by food product engineering that emphasizes food structure property-taste in the future by food producers. Producers of food have to alter the nutritional bioavailability of a food product, which affects a person's sense of satiety, gut health, and overall well-being. Consumer prejudices or a lack of sensory experience with new materials and healthy alternatives can lead to poor food choices and eating habits. Consumers, for example, were more concerned about the environmental impact of meat substitutes than their taste (Hoek *et al*., 2011; Weinrich, 2019) [53, 135]. Food designers and chefs can use molecular gastronomy principles to increase consumer acceptance of food products, which can significantly impact sustainable and healthy eating habits. Gastronomic dishes based on meat substitutes are being developed by a startup called Innogusto (www.innogusto.com), which was founded in 2018. An electric and thermal energy-based method of enhancing one's sense of taste is known as "digital taste" (Ranasinghe *et al*., 2019) [110]. By lowering the temperature of sweet food products, one can reduce the intensity of sweetness (Green and Nachtigal, 2015) [41]. To counter this effect, foods that have had their saltiness and sourness altered through electric taste enhancement could reduce the amount of salt used in the final dish (Ranasinghe *et al*., 2019) [110].

In addition to other external stimuli, social context has the potential to alter the sensory experience associated with food consumption in some way. A "mirror" mechanism is created when people interact with others, allowing them to tune in to the feelings of others by interacting with them. Because positive emotions like happiness enhance the allure and allure of food, while negative emotions like rage detract from that allure and allure (Rizzato *et al*., 2016) [112]. According to Reinoso Carvalho *et al*. (2016) [111], "sonic seasoning" (the use of music to enhance the appeal and overall perception of food) has also been studied. Noise heightens, the umami flavor, reducing the sweetness's impact (Yan and Dando, 2015) [143]. It's an intriguing opportunity to influence healthy habits and accommodate unusual foods in our daily lives by bridging interior design concepts with sensory perception. Using new food packaging methods, the Design for food subdiscipline hopes to cut down on food loss and waste. Food waste and loss can be reduced at the consumer level through the design of resealable packages, consideration of portion size, and clear labeling of "best by and expiration dates," for example. Food waste and packaging design are intertwined in the circular economy. Still, the most efficient solution is to use innovative packaging to extend the shelf life and quality of perishable foods such as fresh fruits, vegetables, dairy, and meat (Halloran *et al*., 2014) [48]. Using packaging as a nonverbal communication medium, consumers and product designers can use packaging to encourage the consumption of healthier and more environmentally friendly products (Plasek *et al*., 2020) [101]. Packaging linguistics has been shown to affect perceptions of flavor and quality. In contrast, Design has been shown to significantly impact the emotional attachment to a product than flavor (Gunaratne *et al*., 2019) [43]. Visual stimuli such as the weight, color, size, and shape of the food container have been linked to its taste preference (Piqueras-Fiszman and Spence, 2011; Harrar and Spence, 2013) [99, 49]. According to a new study, heavy containers makes food appear denser and more satisfying than light containers (Piqueras-Fiszman and Spence, 2011) [99]. 3D printing is expected to be widely used to design food and recycle food waste in light of new techniques in food production, such as additive manufacturing (Gholamipour-Shirazi *et al*., 2020) [36]. By using 3D printing, startup company Upprinting Food has started producing snacks out of waste bread. New technologies may also be introduced into industrial side streams with the help of such initiatives (such as those discussed in the circular economy section). A rising market for healthy food will inevitably lead to new developments in personalized solutions for the food industry (Poutanen *et al*., 2017) [104]. This means that customers will be able to choose foods that are good for their health and values, and they will be able to do so in a more democratic way. Molecular gastronomy techniques and innovative grocery stores, such as 3D printing, can be used to create meals for the home and the community (D'Angelo *et al*., 2016) [21]. In such systems, integrating food structure, property, and flavor will be a difficult task. An incredibly futuristic vision uses concepts from personalized medicine to address a wide range of food-related health issues and reduce the human ecological footprint through personalized or "smart" foods.

Digitalization of food supply in distribution chain

Food waste and loss, biodiversity, diseases, and the availability of resources are just some of the issues that can be addressed worldwide through the digitalization of the food supply chain. Information and communication technology (TCT) advances have made it possible for new technologies to be applied throughout the agrifood supply chain to ensure a safe and sustainable food supply (Demartini *et al*., 2018; Raheem *et al*., 2019) [24, 107]. Information and communication technologys Artificial Intelligence (AI) is a fascinating area to explore. Cognitive computing is a branch of computer science that aims to give machines like computers the ability to think as humans do. These machines can learn, adapt, and make decisions based on the data they collect and analyze (Salah *et al*., 2019) [119]. AI has had a significant impact on the food industry over the past decade. Marketing strategies for agriculture and food sales and eating habits and preferences are included in this category. Also included are food design and safety systems and waste management systems for food. Digital technology has the potential to alter our relationship with food and encourage the adoption of more environmentally friendly eating practices. A better understanding of how the human brain's neural network functions when it sees food is hoped to be provided by AI in the future, which will help consumers make healthier food choices. Fuzzy modeling can help with food gelling agents (such as predicting the impact of different gum-protein emulsifier concentrations on mayonnaise using fuzzy modeling) and liquid-crystalline food structures (by predicting the most stable liquid crystalline phases using predictive computer simulation tool based on field theory).

The development of aroma profiles can also be studied with AI. Electronic eyes, noses, and tongues can be used in the same way as sensory panelists to improve food quality control to analyze food (Loutfi *et al*., 2015; Nicolotti *et al*., 2019; Xu *et al*., 2019) [69, 86, 142]. Companies like Gastrograph AI (https://gastrograph.com/) use artificial intelligence to model consumers' sensory perception, predict their preferences for food and beverage products, map the world of food ingredients based on their personalization of the add, and provide specific advertisements based on the consumer's personalization. Consumers will be able to eat healthy food while simultaneously seeing unhealthy, appealing food in the future due to digitalization. Okajima *et al*. (2013) [91] investigated this possibility by using an augmented reality system to alter the appearance of food in real time dynamically. They found that the way food looks has a significant impact on how people perceive it in terms of taste and texture. By estimating food demand, forecasting waste volumes, and aiding in developing intelligent waste management techniques, AI can help reduce food waste (Adeogba *et al*., 2019; Calp, 2019; Gupta *et al*., 2019) [1, 15, 45]. AI-enabled agents, Internet of Things sensors, and blockchain technology can benefit all parties in the agrifood value chain (Salah *et al.*, 2019) [119]. Multiple parties' transactions can be recorded across an extensive network using blockchain technology (Xu *et al*., 2022) [141]. In a distributed ledger, all parties involved must agree before any records can be changed. This raises the credibility of the data (Olsen *et al.*, 2019) [93].

AI and blockchain technology can be combined to achieve intelligent precision farming and increase consumer confidence in the food supply chain by making the supply chain more traceable and transparent. Various interconnected digital tools support the physical food supply chain flow in their digital counterparts. When all of the blocks have been approved, the chain of transactions can be permanently recorded. Specific details about the process are contained in each blockchain, including the crops used and the machinery used, and the batch number and expiration date. For example, (Kamath, 2018; Kamilaris *et al.*, 2019) [60, 61]. Food supply chain traceability and transparency are becoming increasingly important in food manufacturing management. Monitoring the flow of resources from the source of raw materials to their final destination is possible by using these efficient tools. Recognizing food supply chain bottlenecks and re-allocating food resources accordingly will be critical to reducing food waste in the future. Furthermore, it is possible to combine all of the solutions previously proposed with these digital tools so that we can feed a rapidly expanding world population while preserving our natural resources in the process. Different studies show and prove how AI can be used to achieve intelligent precision farming while also helping to build consumer trust in the food supply chain. The food supply chain's physical flow is supported by a digital flow made up of numerous interconnected digital tools. As blocks are approved and added to the chain, a permanent record of the transaction process is created. Each blockchain contains detailed information about the process, including the crops and machinery used, the batch number and conditions of the product, and its expiration date. Food supply chain traceability and transparency are becoming increasingly important in food management. (Friedman, and Ormiston, (2022); Kamath, 2018; Kamilaris *et al.,* 2019) [33, 60, 61]. Food quality and safety are two areas where they can help track resources from raw materials to their final consumer. Food waste can be reduced by identifying bottlenecks in the food supply chain and reallocating resources accordingly (Kayikci *et al*., 2022) [64]. It is possible to feed the world's growing population while preserving our natural resources by combining these digital tools with the other solutions here."

Impact of the New Corona Disease Pandemic (COVID-19) on Food System

Despite this review's findings, the COVID-19 pandemic has put the food supply system under new strain and stress. A new "severe acute respiratory syndrome (SARS) caused by a novel Coronavirus" has spread worldwide from China since December 2019. It was an unprecedented step taken by several governments to stop the spread of the novel Coronavirus and protect their sanitary systems from collapsing. These actions had a profound impact on global economics and the food system. Customers' purchasing habits were first affected by the lockdown. Panic buying by customers early in the lockdown resulted in a food shortage in several grocery stores, as they purchased canned foods and stockpiled them (Nekmahmud, 2022; Nicola *et al.*, 2020) [83, 85]. It became less extreme as the lockdown went on (Bakalis *et al*., 2020) [10]. There have been questions raised about the Design of the food supply chain because of the difficulties it has had in ensuring that everyone has enough food. According to Bakalis *et al*. (2020) [10], the supermarket/supplier interface is a bottleneck in the Western world's food supply chain because only a few organizations control most of the food. These authors also cited packaging issues as a factor in the lack of basic foodstuffs (like flour). It is recommended by Bakalis *et al* (2020) [10]. that a more regional, decentralized, sustainable, and efficient food system be implemented. Following the COVID-19 pandemic, which revealed the system's vulnerability, automation (robotics and AI) may be able to assist in maintaining the food supply chain.

Every aspect of the food system must be rethought from a resilient and sustainable perspective to guarantee that everyone has access to adequate, safe, and healthy food. Policymakers must be included in this process (Bakalis *et al*., 2020; Galanakis, 2020) [10, 35]. Another problem that arose due to the lockdown was food waste. Restaurants, caterers, and food manufacturers all saw an increase in food waste due to the food supply chain being disrupted and broken (Bakalis *et al*., 2020) [10]. Food waste has become a more pressing issue for many people, and they have taken steps to reduce it at home. Consumer behavior has been affected more by the COVID-19 lockdown than educational efforts to reduce food waste (Jribi *et al*., 2020) [57]. Covid-19 has shown that designing food products that boost our immune systems and prevent the spread of virions throughout our food chain is critical (Galanakis, 2020; Roos, 2020) [35, 114].

Infectious virions can enter the food supply chain during the production, handling, packaging, storage, and transportation stages of food production, handling, and storage. Preservative-free foods and animal products are more likely to cause this. Packaging and handling of minimally processed foods should be considered to reduce viral transmission while minimizing waste. Inactivation of virions can be reduced through a better food product design that considers the interactions between the temperature of inactivation, food water activity and the effects of food matrix on virions' survival." (Roos, 2020) [114]. Food security by 2050 necessitates the implementation of actions throughout the entire food system that can counteract exceptional circumstances like the global pandemic caused by the novel Coronavirus.

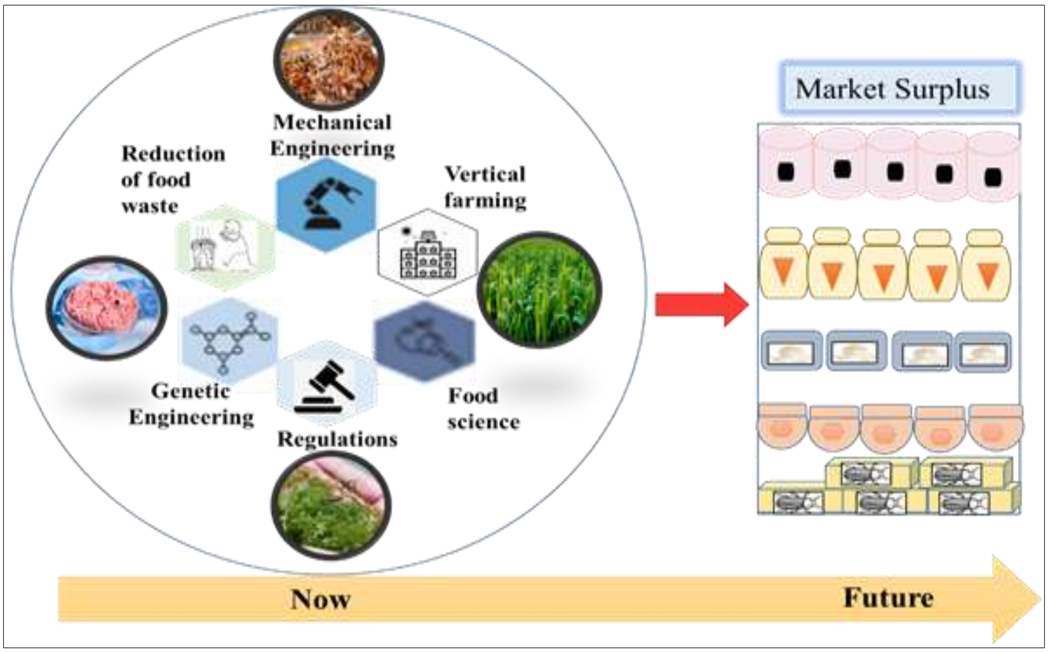

Fig 2: Graphical Abstract

Cover letter

The ability of the earth to produce new resources is being depleted by the ever-increasing human population. One of the most pressing issues we face right now is how we will feed the world's growing population. Several risks and challenges, some of which are discussed below, can severely limit the ability to expand and maintain a sustainable global agri-food system in order to meet these demands.

Higlights: Concerns about food safety, nutrition, post-harvest losses, inconsistencies in regulations, and the attitudes of consumers are all major obstacles that must be overcome in order to preserve food security and sustainability. Alternative protein sources, insect flour, nutrigenomics, 3D food printing, biomimicry, food engineering, and merging technology are some examples of potential solutions. Other possible solutions include advancements in food processing technologies, nanotechnology, innovative food formulations, and the use of genomic approaches.

Conclusions and Outlook

There must be a shift from our current food system to a more efficient one that is better for our health, environment, and customers in the next 30 years if we want to be safe from hunger and keep our natural resources. On the other hand, this change is complicated and not easy to make. First, we need to move from a linear to a circular economy, where waste and side streams are used to create new sources of food materials and ingredients. This will make more efficient use of the available bioresources. Second, thing is that more food needs to be made. These include vertical farming, genetic engineering, cell agriculture, and unconventional sources of ingredients like microalgae, insects, and wood-derived fibers. These things can help by making land more efficient, increasing food and ingredient production, shifting production from global to local, and making waste into ingredients with new functions. However, food design is needed to create sustainable food with new ingredients and technologies that people like. This is when food is thought up, built, and engineered in its structure, appearance, functionality, and service. These solutions could be paired with digital technology, giving them an extra boost. Many tools can help manage the whole food chain better to make sure it's safe and healthy, help develop new ingredients, structures, and structures, and change how we think about food, leading to less food-related disease. For example, AI, blockchain, VR, and AR can help. Imagine that people might be able to 3D print a steak at home with cells or plant-based proteins in the future. AI and biosensors might help us learn more about how our digestive systems work with food ingredients and structures, which could help us make 3D-printed steaks better for us in terms of nutrition and taste. The food made in the future may also be able to control how easy it is to digest and how many nutrients are will available to the body. In this case, two people who eat the same food would have it absorbed in different ways. People in the future would be able to solve food-related illnesses like obesity and type 2 diabetes, but the Earth would still be able to grow new bioresources. The strategies and solutions we've talked about here may only be able to help us reach a sustainable food supply by 2050 if they are supported and encouraged by standard policies around the world. Innovations in food science and technology can ensure enough excellent and healthy food for people to eat. They can also help people change their eating habits to eat more sustainably. Finally, the recent COVID-19 global pandemic has shown how important it is to have a food system to handle unusual and unexpected events. All of these things may help us achieve food security by 2050.

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