The Future of Food

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By

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PREFACE

Since the beginning of human history, nearly all of our days have been spent in the effort to search for, collect, produce, and consume food. Human destiny has been connected to food, and vice versa. If food is available, humans can survive; and people decide on the existence of types of foods. The future of food has started to change in tandem with population increase and advances in science and technology. The other parameters for the future of food include consumer demands, health problems, novel techniques, higher or lower calorie consumption, nanoscience, technology, social and cultural developments, new food sources, changes in lifestyle, the situation of women, and global warming.

This book contains information about the future of food from a major scientific research activity based on the integration of many different data. This book is suitable for regular readers, students, politicians, industry-oriented people, scientists, and people outside the food industry.

This book contains eight chapters. Chapter 1: An Introduction to Foresight on Food and Agriculture Industries gives general information about and ideas on the future of food. Chapter 2: The Future of Food and Nanotechnology gives a special perspective on what types of nanotechnology-based applications will impact the future of the food industry. Chapter 3: Foodent-ropy: Entropy of Food due to Energy Demand is a horizon scan and questionnaire on the relationship of food vs. bioenergy. Chapter 4: The Future of Food and Global Warming attempts to answer how global warming will affect food security for people today and in the future. Chapter 5: The Future of the Meat and Dairy Industries as Basics gives a perspective on the future of the meat and dairy industries. Chapter 6: Food and Agriculture Technologies in the Future is about novel, innovative and expected futuristic applications of developing technologies on the food industry. Chapter 7: Special Chapter: The Next Big Migration to Mars, Spacefoods, Marsfoods, Mars-omics, and Industry M.0 is about the future of life and the food industry on Mars. Chapter 8: Determination of Calorie and Food Quantity Requirements for the Year 2050 includes mathematical calculations for the amount of food that will be needed in the year 2050. In the glossary, the future terms for the food industry are given.

In this book, you will find answers to the following questions:

- Future projections for food and the population
- Industry X.X
- Artificial intelligence and food
- Innovative techniques
- Future life and food
- Kitchens of the future
- Cooks and chefs in the future
- Energy and food relations in the future
- Food-omics and its future
- Food, agriculture, energy, and industry
- Lifestyles in the future
- The situation of water in the future
- Insects as a food source
- Tailor-made foods
- GMO, genetics and safety
- Oil as a fuel or vegetable oil
- Artificial sensory food flavouring
- Mars food plant mission (#MFPM)
- Big data and the food industry
- Smart farming
- Unmanned aerial vehicles
- Mars-omics and Space-omics
- Industry M.0 (Mars.Zero)
- Foodent-ropy

CHAPTER ONE

AN INTRODUCTION TO FORESIGHT ON THE FOOD AND AGRICULTURE INDUSTRIES

1.1. What is food?

Food was thought a simple thing until the last century. It was only planted, cultivated and consumed, not fabricated or modified by technology. However, today a food may be produced artificially, nano-capsulated, genetically edited, printed, and even planted underground or above the sea or even on another planet, like Mars. For this reason, we should redefine food. According to recent developments, food can be defined as a consumable matter that is obtainable with suitable technologies or operations such as lab-growing, printing and genetic modification or nanotechnology applications, either with the utilization of soil or not, and grown in any suitable place.

1.2. History of food

Food and humans shared the same destiny in the past and will also share the same destiny in the future. Anthropology shows that food in ancient times changed human biology. In the first era, the hunting and gathering era, people ate wild fruits, grass and other plants, and then learned how to hunt; as a result, their metabolism started to change. Meat protein changed their brains and intestinal activities. In the second era, the agriculture era, people stopped moving around and grew most of their food. They gained some properties and lost some properties coming from the hunting and collecting era. Additionally, the role and position of women changed. In the third era, the industrial era, everything changed. Life and nourishment styles changed. People learned to eat fast food and ready-to-eat foods due to the new lifestyles. The role and position of women changed again (Bayram 2018a).

In ancient times, there were four districts: Africa, the Middle East (Mesopotamia), Asia, and America. When people started to discover and migrate to these districts, they discovered new foods. These foods were the "Four Horsemen of Armageddon": sorghum (Africa), wheat (the Middle East/Mesopotamia), rice (Asia), and corn (America). Each one determined the destiny of the people in Africa, the Middle East, Asia, and America, respectively. Sorghum was the first product of the first district for the people, then some people migrated to the Middle East, the second district for humans, and learned to grow wheat. When people migrated to America, they learned about corn. When people went to East Asia, they discovered rice. This legend is parallel to the Genographic Project (the history of humans over a period of 60,000 years). Additionally, each culture accepts these food gods/goddesses (Bayram 2017, 2018b) in their ancient districts. (NOTE: The term "district" was used in this paragraph on purpose, it is not a mistake. The authors wish to show a district region instead of a continent).

When cultures started to travel along the Silk and Spice Roads, they brought food products with them. Then, other people learned about foods from other worlds, like spices, wine, fruits, nuts, vegetables, pasta/noodles, dried meat, corn, rice, coffee, tea, and bread. When America was discovered, new foods were transferred to other parts of the world.

In the future, some of these ancient roads will be rediscovered and they will affect human destiny based on health and food (Kickbusch et al. 2018).

Many things were also learned from nomads and the sedentary societies. For example, the first fast food may have been dried meat, which was used by Genghis Khan to feed his soldiers during military expeditions. His soldiers mixed hot pebbles with water and dried meat to prepare a soup when riding during their expeditions. It was a typical fast food for a mobile life.

In addition, as a culture, the nomads and caravan peoples do not talk while they are eating. It is today a traditional rule based on this historical behaviour. In the olden times, these was not much time for nomads and caravans on the road; therefore, meals had to be eaten as quickly as possible. In contrast to nomads and caravan-origin peoples, sedentary societies had long conversations during lunch and dinner (slow food), so it is again historical behaviour due to the availability of time (Bayram 2018a).

Wars also pushed the development of new food processing techniques. Canning, salting, vacuum packaging, and modified food packaging, etc. helped keep armies mobile. Canning especially was a war strategy technique discovered in Europe.

Another issue is the lifestyle of the modern era. Today, time for preparing food is limited so microwaving, refrigeration, frozen food, robotics, and ready-to-eat foods are the products of this new lifestyle.

The next step will be space foods. In the future, people will need new foods and food production and preservation techniques for space travel and life on other planets. Therefore, human destiny will go hand in hand with the destiny of food.

1.3. What is the future?

The words future, estimation, expectation, prediction, and foresight are synonymous. In this book, these words are used to express the future. The future may be thought of as a combination of expected and unexpected things. It can be roughly estimated but hard to estimate closely. In reality, every second that has not been experienced in life can be considered as the future. So, even one second later is the future, but it is the very near future. In this book, the aim is to explore the future of food within approximately the next era.

1.4. Past ideas about the future of food

In 1893, Mary E. Lease, a feminist and activist, thought that the future of food may entail more convenient preparation and cooking via artificial foods. In 1896, Marcellin Berthelot, a French chemist, thought that the future of food would be “meal pills”. In 1900, the *Boston Globe* predicted that food would be transported conveniently via pneumatic tubes in 2000. In a more ambitious endeavour, Noel Hodson’s Foodtubes project proposed that food would be delivered to retailers via an underground capsule-pipeline system, thereby saving energy and reducing pollution. Also, Clifford Simak’s novel, written in 1961, describes so-called butcher plants that can provide protein similar to meat. His novel described the first genetically modified food, a "flavr savr" tomato, 30 years ago (Hilary 2016). In 2000, the following topics are considered important for the future of the agriculture industry: precision agriculture, low leaching cropping systems, the management of soil biological processes, and maximum recirculation (Kirchmann and Thorvaldsson 2000).

The future of food has been gaining in importance for humanity. This is probably because of the decreasing natural sources due to the rapidly increasing world population. Studies have been carried out about the future of food and the agriculture industries (Mermelstein 2002; Laio, Ridolfi, and D’Odorico 2016; Hilary 2016; Gökirmakli and Bayram

2017a; Eckardt et al. 2009; Bourgeois 2016; Beddington 2011; Bayram and Gökırmaklı 2018), global warming (Gökırmaklı and Bayram 2016), the dairy industry (Kay 1942, Gökırmaklı and Bayram 2017), the meat industry (Gökirmakli and Bayram 2017b), omics technologies in the food industry (Bayram and Gökırmaklı 2018), the pasta industry (Gökırmaklı and Bayram 2018), and the grain industry (Bayram 2017). In addition, some non-governmental organizations, such as the Food and Agriculture Organization of the United Nations (FAO), have prepared reports on the future of food and agriculture (FAO 2017).

As a futurist projection, food will have the following properties: easy, personal, digital-covered technology, will have multiple tastes, will be sustainable, natural, functional, and healthy.

1.5 Relationship between the food sector and agriculture

In the 1800s, the main problem for agriculture was the limited production of agricultural products, like foods (Beal 1883). Today's agricultural system overcame this problem with the green industrial revolution but, unfortunately, starvation is still a big problem in many parts of the world. With the growing global population, food safety is expected to become one of the most important issues in the near future (Tübitak 2003). The United Nations reported that the population is projected to be 9.7 billion in 2050, and 11.2 billion in 2100 (UN 2015). As the population increases, the agricultural area per person decreases. Moreover, there are some chemical and physical problems being found in the soil, such as salinity, alkalinity, acidification, mineral nutrient deficiency, pollution, erosion, and loss of organic matter. In addition, based on some calculations, 38% of the 1.47 billion hectares of cultivated land in the world is in a state of degradation (Tübitak 2003).

The food sector has relations with the entire food production process from soil to industry, and, more importantly, it is one of the most vulnerable industries affected by weather conditions (Tübitak 2003). Climate change and global warming are two important issues that affect today's food security, and are expected to have effects on food security in the future. Increasing temperatures are probably having positive effects on people who live in cold regions. On the other hand, people who live in hot regions are probably affected by climate change adversely. As a result, it is totally expected that climate change has more negative effects on global food security than positive results (IPCC 2014).

Another event threatening food security is the decrease in biodiversity. At the start of the Green Revolution, higher efficiency crops were favoured and so the variety of plant foods decreased in most countries around the world (Çetiner 2011). In the near future, the expectation is that both crop and animal production will increase. For example, the demand for meat is projected to reach 327 million tonnes in 2020. For this reason, corn is expected to be the most required crop (Tübitak 2003). British scientist John Beddington suggests that people will probably need 50% more energy, 50% more food and 30% more water in 2030. However, due to climate change, it will be harder to meet these demands (Yıldız 2014). Similarly, the demands for wheat, rice, fruits, vegetables, and other types of food commodities are only going to increase with time.

Today's consumers are more careful about their health and the effects of technology on the environment. They desire to know all aspects of a technology before they use it. For this reason, most of the technologies that could totally revolutionize the feeding habits of people, from growing to consuming, are not used directly in the food and agriculture industries. Nanotechnology and genetic modification technology are two such technologies. Nevertheless, an increasing number of consumers benefit from these new technologies daily. For this reason, the future of these technologies is promising but there are unpredictable risks.

Beyond nanotechnology and genetic modification technologies, more sustainable and ready-to-use technologies have emerged, such as three-dimensional printers (3DP), vertical agricultural systems and industry 4.0, which are also suitable for food production. Unmanned aerial vehicles may also change the logistics in food and agricultural industries in the future in a more sustainable way.

All of the above-mentioned topics are detailed in this book in terms of their impacts on the food and agricultural industries in an attempt to give a general view of the future of food.

1.6. World population

The known population of the world in ancient times was 15 million. In 1600, the world population was about 500 million; in 1750, it increased to 750 million, and to 2.5 billion in 1950 (Foster 2008). In 2015, the number was greater than 7 billion (exactly 7,349,472) (UN 2015). In a medium variant projection, the world population is expected to reach approximately 10 billion (UN 2015). At the present, 1 billion people are malnourished, and, according to FAO, to feed all the people around the world, food production needs to increase by 70% (Odegard and van der Voet 2014). World population growth is given in figure 1.1, according to UN (2015) and De Long (1998).

After the Second World War, population growth changed, the "baby boom" period, because of the advancements in medicine, science and the economy, and decreasing fertility (Yaşa and Mucan 2010). This situation resulted in an increase in the number of mature people in the world (Yaşa and Mucan 2010). According to the age pyramids, the number of mature people is projected to increase further in the future; Wiener and Tilly (2002) predict that the number of mature people will increase by 135% between 2000 and 2050. In line with this, the food products oriented towards mature-aged people may become more important in the future than today, and will be more commonly consumed around the world.

1.7. Global warming, climate change and environmental problems

Today, environmental problems include excessive population growth, the destruction of the ozone layer, global warming, the extinction of species, the loss of genetic diversity, acid rain, nuclear contamination, the destruction of tropical forests, and the destruction of high forests and wetlands. Soil erosion, desertification, flood, famine, the contamination of ground water, the pollution of estuaries and seas, the destruction of coral reefs, oil spills in the sea, overfishing, coastal erosion, the adverse effects of the pesticides used to control insects, excessive population growth, and the consumption of non-renewable sources are also manifest (Foster 2008). Soil is affected by most of the above-mentioned situations so food production is also affected. If global warming exceeds 2^{o}C, the limits inherent in today's food system will be enforced. For this reason, food and agricultural policies are expected to change in the coming decades to mitigate the adverse effects of global warming (Fresco 2009).

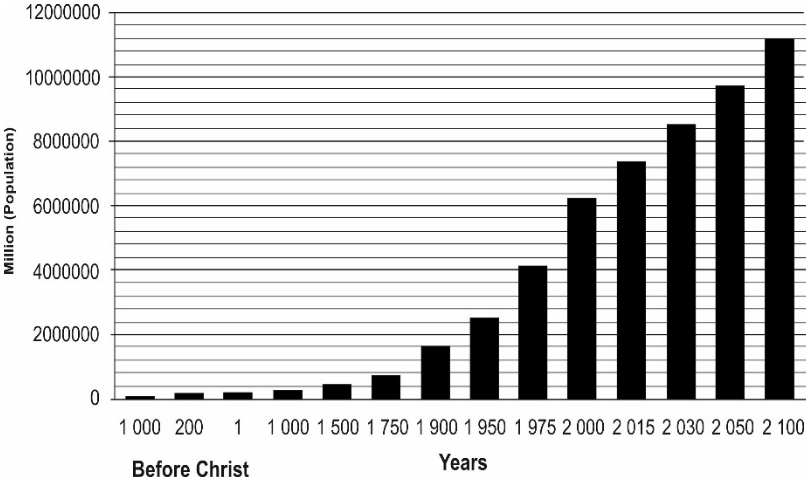

Figure 1.1. World population number along the history and expected in the future. Derived from data presented in UN (2015), De Long (1998).

1.8. The effects of the increased concentration of greenhouse gases on global warming and climate change

Climate change was mentioned for the first time in 1979 during the World Climate Conference. The United Nations General Assembly qualified climate change as a common concern for mankind on 6 December 1988, a breaking point for the issue (TTGV 2011). Global warming is the result of accumulated anthropogenic greenhouse gases in the world atmosphere. Some of the most important greenhouse gases are carbon dioxide, methane, water vapour, ozone, and nitric oxide. The carbon dioxide concentration in the atmosphere has increased from 280 to 400 ppm, and elevated CO_2 has consistently shown positive effects on plants in terms of mild temperature increases. This situation affects most of the world ecosystem by causing climate change (Chae et al. 2016). In figure 1.2, the expected change in carbon dioxide in the atmosphere is shown up to the year 2050. When the figure was analysed, a significant increase in the carbon dioxide concentration with time was observed, and if such trends continue, food security will probably be affected adversely. According to Galip (2006), if the trends continue, after 30 to 40 years, there may be no arable soil for agricultural use, or even a liveable world.

The effects of global warming are increasing day by day. For this reason, glaciers on the poles are melting and the level of the sea will probably rise rapidly. Some countries established at sea level or below, such as Holland, Germany and Denmark, will probably lose major areas of fertile soil. This situation will probably cause a decrease in food production around the world and may cause a hunger crisis (Galip 2006). However, some positive effects of climate change and global warming are also present. For instance, at today's levels of CO_2 concentrations, the efficiency of corn and winter wheat crops will increase in 2020, 2050 and 2080, based on a projection. Moreover, the vernalization time of winter wheat and total time for plant growth are expected to decrease (Tezcan, Atılgan and Öz 2011).

World climate thermodynamics are expected to change due to global warming (Pimentel et al. 1992). For example, the rate of evaporation is expected to increase due to temperature increases and this will probably cause an increase in plant transpiration (Pimentel et al. 1992). In addition, an increase in temperature may cause an increase in the growth rate of insects (Johkan et al. 2011). This may have some undesirable results, such as a 25% to 100% loss in agricultural products in the USA (Pimentel et al. 1992). Moreover, mycotoxins may increase with increasing temperatures and this may have some negative effects on food security (Vermeulen 2014). However, fortunately, people have understood the negative impacts of global warming. For this reason, some precautions have been recently put in place. For instance, in 2015, at the Group of Seven (G7) (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) summit, the leaders decided to "decarbonize" the global economy by the end of 2100 (Jones and Warner 2016). If this decision is applied, fossil fuel usage will probably decrease in the future.

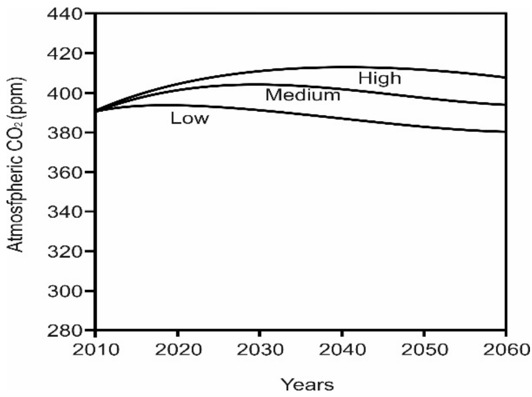

Figure 1.2. Projection on global carbondioxide concentration change between 2010-2050 (Davis, Caldeira, and Matthews 2010). Reprinted with permission.

1.9. The situation of water in the future

Water is a vital substance for all living organisms and its quality has an effect on the quality of life (Akın and Akın 2007). Most of the world, 75%, is covered by water but only 0.74% of that water is suitable for human consumption (Akın and Akın 2007). More importantly, most of the fresh water is not suitable for direct usage (Yılmaz and Peker 2013). For this reason, more than 230 million people in 26 countries lacking access to water. Eleven of these countries are found in Africa (FAO 2015). Moreover, the amount of usable water has decreased around the world for reasons such as the rapid increase in population, developments in industry and technology, and the lack of awareness of efficient water usage (Akın and Akın 2007, Yılmaz and Peker 2013). Because of this, food security is threatened.

A water crisis may be defined as the lack of water or usage for over 1 billion people and the lack of infrastructure for water and wastewater for about half of the world population. In the coming decades, according to forecasts, the demand for water is going to increase daily, especially for big cities. Over the next 20 years, an estimated extra 17% of water will be required in developing countries for use in agricultural production. In line with this, total water consumption is estimated to increase by 40% in the coming years (Orhon et al. 2002). In addition, because of the increased population, the water available per person is projected to decrease to 4692 m^3 in 2025 from 6840 m^3 in 1995 (Yılmaz and Peker 2013). As a result of today's conditions, food and water scarcities are already manifest in some parts of the world in the 21st century (Bruins 2000). Crowded regions, such as the Mediterranean, the Middle East, India, China, and Pakistan, may face water scarcities in the future (Xiong et al. 2010, Hanjra and Qureshi 2010). Water demand will become more competitive if demands for energy, food and mining increase. In addition, the effects of climate disorders may be expected to be seen first in the global water system. The renewable water supply system should be changed to overcome the adverse effects of climate disorders (Yıldız 2014).

Ohlsson (2000) investigated the United Nations Social Water Scarcity Index analysis of 159 countries. In these indexes, the situation of water in 1995 and the projections for the situation of water in 2025 were studied. Based on these indexes, water scarcity has a more rapid impact on social aspects. These impacts are estimated to increase the risk of wars and conflicts between countries (Yılmaz and Peker 2013). Gleick (1994) suggested that water may cause wars between the nations in the Middle East if used for a military purpose, or be taken as a reason for war (Yılmaz and Peker 2013). On the other hand, at least 3600 international agreements about water were signed between the years 805 and 1984. According to the statistics, between 1918 and 1984, there were 412 problems between countries bordering the same river, and 7 of these were related to water (Yılmaz and Peker 2013).

1.10. Information technology (IT) and futuristic kitchens

Some changes in lifestyle and the entry of women in the workforce have changed cooking habits. In line with this, ready-to-use and convenience foods are more common, and for this reason, some cooking apparatuses (microwave, kettle, refrigerator, 3D-printer, robot etc.) will become even more popular in the coming years. Ready-to-use and fast-food industries will expand as a result. Traditional recipes will probably change and the information traditionally transferred from mother to daughter may disappear in the future. For example, the expectation is that refrigerators will give information about the available amount and the type of foods inside them. They are also expected to detect expired products, prepare shopping lists based on usage preferences and give recipes based on the available foods (Yumurtacı and Keçebaş). New-generation refrigerators will be smart, will manage stocks, and order directly from e-supermarkets.

According to 2015 data, food expenditure in the house is nearly equal to the expenditure on food out of the house, especially in the USA. In figure 1.3, how money was spent on food at home versus food outside the home based on percentages between the years 1869 to 2013 is illustrated. The trends suggest that food consumption outside the home will increase in the coming decades. Industrial and prepared food consumption are also expected to increase as well as the number of fast-food and franchising restaurants.

A new technology called 3-dimensional printing (3DP) has been developed. It is predicted that its use will be more common in the coming years and with this technology, personalized food production technology will begin (Sun, Peng, Zhou et al. 2015). Moreover, it is expected that this technology will increase food security by overcoming the problems related to the low efficiency and high production prices of the food industry (Sun, Peng, Yan et al. 2015). The 3D printing techniques applicable to food design are outlined in a study carried out by Godoi, Prakash and Bhandari (2016).

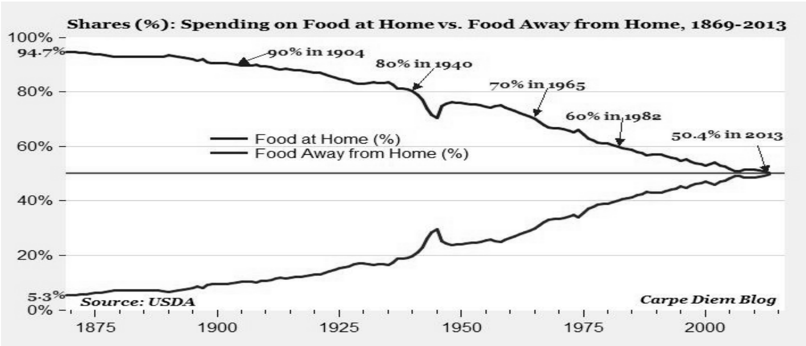

Figure 1.3. Money spending on food at out of home vs. home for USA, 1869-2013 (Perry 2015). Reprinted with permission.

Industry 4.0 is the superposition of several technological developments that embrace both products and processes. Industry 4.0 is related to the so-called cyber-physical systems that describe the merger of digital with physical workflows. In production, this means that computer-based processes accompany the physical production steps. Cyber-physical systems include compute-and-storage capacity, mechanics and electronics, and they rely on the Internet as a communication medium. Another related technology is the so-called Internet of Things, defined as ubiquitous access to entities on the Internet. The economic effects of smart products and Industry 4.0 are manifold. Traditional settings will also profit from Industry 4.0. For example, the ability to provide more individual products or products that are malleable once received by the customer may reduce the number of product returns (Schmidt et al. 2015).

Industry 4.0 can be expected to revolutionize all industrial systems, including industrial food production systems. Smart industrial machines will be able to connect to each other, and the fully automated systems will require nearly no human intervention. In line with this, it is expected that fewer people will work in factory production. Since human intervention in production systems is expected to be unnecessary in the coming years, the systems will need to be more effective. In addition, less wastage from factories in terms of both packaging materials and foods is expected in the future with the aid of Industry 4.0.

Robot technologies have recently gained in importance with the developments of Industry 4.0. Instruments that control vegetable growth, as well as robotic pickers, are being tested. In addition, sensors that can aid in monitoring the health of livestock and the quality of soil are undergoing improvements in their technologies. Even though some of these applications and technologies are already available, most of them are at the research stage in labs (King 2017). Moreover, some companies have recently begun to test growing and harvesting crops without human intervention in the field (King 2017).

1.11. Foresight for the future of food and agriculture

According to the study carried out by Thornton (2012), potato production may decrease in the future due to global warming. This situation may result in the planting and growing of bananas at high altitudes instead. For this reason, bananas may become a basic food instead of potatoes in the future. In the same study (Thornton 2012), corn, rice and wheat production are predicted to decrease due to raised temperatures while the production of cassava and cowpea will increase.

According to Hoagland and Arnon (1950), the first studies for soilless agriculture were carried out in 1860. Also, according to a recent study by Hussain et al. (2014), soilless agriculture is the fastest developing sector of all agricultural sectors. Moreover, in the same study (Hussain et al. 2014), it was predicted that soilless agriculture may be commonly used for food production in the future.

Vertical agriculture has also been the subject of recent studies (Kozai, Niu and Takagaki 2015, Besthorn 2013, Banerjee and Adenaeuer 2014). In Singapore, one example of vertical agriculture is Sky Green (Christ 2013). This method requires 75% less water, soil and fertilizer than the traditional agricultural method used to grow vegetables (Christ 2013). In addition, many advantages of soilless agriculture were mentioned by Despommir and Ellington (2008). For example, it may seriously reduce fossil fuel utilization and the chemical contamination caused by agricultural pesticides, and provide more food in small areas (Despommir and Ellington 2008). In another study carried out by Al-Chalabi (2015), it was mentioned that vertical agriculture utilization in cities has important potential. Based on this information, it may be commonly used to produce food in the future.

Functional foods are also probably going to be used more commonly around the world in the future. Recently, the production of these foods has accelerated and many more functional food products are being produced (Alaşalvar and Pelvan 2009). Nutrient-gene interactions especially offer a significant opportunity for future food development focused on lowering the risk of disease (Mermelstein 2002). Functional genomics will probably establish rapid methods of screening for genes to develop food tailored to the human polymorphisms associated with chronic disease. New food products will probably target cardiovascular disease, cancer, diabetes, obesity, and osteoporosis (Mermelstein 2002). However, according to another study (Boğaz 2003), fast-food type foods will remain as an important way of satiating hunger in the future, like the situation today. If levels of education and consciousness improve, healthy and functional foods will probably be consumed more commonly than fast-food type foods in the future. On the other hand, insects have gained in popularity as a protein source. At present, two billion people consume insects as part of their daily diet, and it is estimated that more than 1900 insect species are available for human consumption (Pal and Roy 2014). In the far future, foods derived from insects and insect cell cultures may be utilized for human consumption during long journeys to space (Mlcek et al. 2014, Durst et al. 2010).

An innovative technology called man-made meat production technology (lab-meat or artificial meat) is emerging as an alternative to the classic meat production technology (Orzechowski 2015). There are many studies about this novel technology today and, according to scientists, the usage of this technology in the future is still unpredictable (Bonny et al. 2015) due to doubts about its sustainability, the acceptance of it by consumers, ethical concerns, high production costs, and its impact on the health of both humans and the environment (Bonny et al. 2015). Despite the fact that its usage and future are unpredictable, it is promising technology, so when the conditions are fulfilled, a more common utilization will probably take place.

Cobia, *Rachycentron canadum,* is a preferable fish species for fish culture because it is fast-growing, has high economic value, has a high adaptability to cage culture, and has a high resistance to disease (Sun et al. 2006). Since it has many advantages, it may be an important fish species for the fish industry in the future (Sun et al. 2006). Also, according to Grey (1987), barramundi may also become an important and valuable product in the future. On the other hand, the curators' *Farmstand Forecast* looks at alternative foods for the future, such as the historical "miracle" crops breadfruit and *Chlorella* algae (King 2016).

1.12. Present and future applications of nanotechnology in the agriculture and food industries

The word "nano" comes from Greek, and its meaning is "dwarf". Technically, it means 10^{-9} or parts per billion (Demirbilek 2015). Today, there are many applications of nanotechnology in the food and agricultural industries (Tarhan, Gökmen, and Harsa 2010).

Food production, the development of novel functional foods, the carrying of bioactive materials, the controlled release and detection of pathogens, and extending the shelf life of food products with the aid of novel packaging technology are some potentials of nanotechnology. In the coming years, it will be possible to attain the desired properties of a food related to its texture, aroma and content with the aid of nanoparticles from proteins, carbohydrates and lipids (Tarhan, Gökmen and Harsa 2010).

The molecular synthesis of foods is promising. For example, in the future, through synthesizing, meat may be obtained without killing any animals, and vegetables may be obtained without harming the environment. Before cooking or serving, the foods can be synthesized and refrigerators will no longer be required (Hall 2014). 3DP has started to develop further in this direction.

Nanotechnology provides an important base from which to treat diseases at the molecular level, instantly detect diseases, improve the sorption ability of plants, and a whole lot more. These applications may revolutionize the food and agricultural industries. In the coming decades, with the aid of nano-sized catalyzers, pesticides and herbicides will be more effective even at lower levels (Demirbilek 2015).

In agricultural production, environmental changes may be monitored precisely and in this way more efficient production will be possible. Also, with the aid of nanotechnology, agricultural waste can be reduced or re-used in more efficient ways (Demirbilek 2015).

A recent prediction about the developments of nanotechnology is that technology will affect lives by the year 2025. Like other technologies and developments in the food industry, the reliability and the acceptability of the technology to religious concerns are probably the key factors determining its use (Süfer and Karakaya 2011).

In figure 1.4, the present and future trends in the global food industry are presented. Firstly, sustainability is the most important topic, according to figure 1.4. Especially with the increasing effects of global warming, sustainability will become even more important around the world. In addition, emerging novel technologies are able to protect the organoleptic properties of foods better. This trend will probably be maintained in the coming decades. The demands of consumers are for more R&D-based foods with improved naturalness. The Z+ generation especially is interested in novel developments. As such, one can say that innovative and R&D-based food products may be more common in the future.

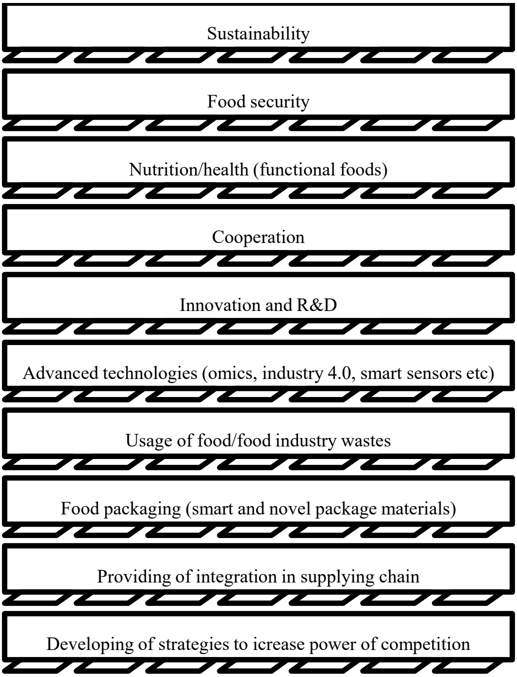

Figure 1.4 Today and future trends in global food industry. Derived from Ata, Çakar, and Işıtan (2011).

1.13. The year 2030 (the interim period before 2050)

More food than ever is needed for the growing population. Trends indicate that cereal production needs to double by 2030 and 75% more meat will be necessary. Climate changes will have an effect on these factors as well as on plants, CO_2 levels, day and night temperatures, the seasons, sea levels, and so on (Fresco 2009).

In 2030, the world will be completely different. Fresco (2009) mentioned some examples:

- Semi-urban agriculture may be utilized to produce intensive amounts of poultry and vegetables.
- By using novel living beings such as the mud worm, aquaculture may be utilized.
- Some plant nutrients may be obtained by utilizing municipal wastes.

- Protein requirements may be met by algae in the future.
- Instead of meat, lupine or soybean may be used.

In addition, the demand for water in the year 2030 is expected to be 50% higher than today's level (Saguy et al. 2013). Since the world has limited resources, technologies are required to enable these limited resources to be used more efficiently. Alternatively, lab-meat (artificial meat) may be used as a protein source instead of animal-based protein.

1.14. The future of biofuels with respect to the food industry

Biofuel is gaining in popularity around the world. The countries that have the highest production of biofuels are Brazil (37%), the USA (33%), China (9%), and India (4%) (Taşdan 2005). In some reports it was suggested that the present biofuel production has not had a major direct effect on food prices (yet), which is in contrast to public perceptions (Fresco 2009). Globally, biofuel production covers 1% of all agricultural areas. This ratio is too small to directly affect food prices (Fresco 2009). Also, with increasing consciousness, renewable energy source usage is increasing day by day (Ellabban, Abu-Rub and Blaabjerg 2014). Moreover, to prevent any conflict between food and biofuel production, new and promising types of biofuel production technologies, known as second and third-generation biofuels, have been studied (Sims et al. 2010, Lü, Sheahan and Fu 2011, Demirbaş 2011, Daroch, Geng and Wang 2013, Antizar-Ladislao and Turrion-Gomez 2008). If these technological developments are maintained in the coming years, it could be predicted that in the year 2050, there will be no conflict between food and biofuel production.

1.15. Food for Mars mission and space travel

John Glen consumed the first food in space from an aluminium tube on the third manned Mercury mission over 50 years ago. The cubed foods, which originated from cereal-based food products, were an important part of the earlier space food systems. Some novel technologies, such as dehydration and irradiation, were developed to improve the quality of foods for the space missions (Bourland 1993).

Nutraceuticals or pharmafoods may be components of long-duration mission food systems in the future once their health effects have been confirmed. It is hard to know exactly which food system will be available but it should be safe and nutritious (Perchonok and Bourland 2002).