

## 1

## The Role of Agriculture in Today's Food Industry

*The ultimate goal of farming is not the growing of crops, but the cultivation and perfection of human beings.*

—Masanobu Fukuoka

### 1.1 Introduction

In every form, agriculture has always been and most likely will always remain the twin sibling of food and especially the food industry. We all seem to be rather clear on what “agriculture” stands for but let me provide a short definition, so that we are on the same page.

Agriculture means to use natural resources to produce commodities which maintain life, including food, fiber, forest products, horticultural crops, and their related services. This definition includes arable farming or agronomy, and horticulture, all terms for the growing of plants, animal husbandry and forestry. (“Agriculture,” n.d.)

Merriam-Webster gives a slightly shorter, yet rather similar definition:

The science, art, or practice of cultivating the soil, producing crops, and raising livestock and in varying degrees the preparation and marketing of the resulting products. (“Agriculture,” n.d.)

There are some important keywords to be found in both of these definitions, such as: *arable farming, cultivating the soil, crops, horticultural crops, fibers, forest products, growing plants, livestock, animal husbandry, preparation and marketing of resulting products, and food.*

The most important message though is using natural resources to produce commodities (mostly food but also fibers for cloths and wood for shelter and fuel, at least in part), which maintain life. Maintaining life and all that goes with it is really the major driver here; agriculture in all its forms and shapes and all that derives from it is the basis of life. Without it we could not really exist, let alone survive.

Although all this is pretty obvious, it is definitely worthwhile to remind us of these various elements and roles and to put them in a right perspective. So let's briefly list and define the four major building blocks that are necessary for life and agriculture to exist in the first place.

### 1.1.1 The Four Building Blocks

These supporting building blocks are necessary not only for life at large but also agriculture in any form.

The *first* building block is water and hasn't been mentioned yet. Water plays a crucial role; it is one of the cornerstones of life and growth on this planet. Interestingly enough, whenever my colleagues at JPL/NASA launch a rover to Mars, one of the great questions they want to find answers to is: "Is there or was there water on that planet?" Seems that there was and actually still is—at least traces—and that could mean that, although quite some time ago (maybe hundreds of millions or even billions of years back), there was enough water on Mars to sustain growth of agricultural matter of one kind or another.

This just shows how critical the presence of water is for any organic growth—water, together of course, with other compounds such as oxygen, hydrogen, carbon, nitrogen, sulfur, and phosphor, to name just the most important ones. These atoms, in their various molecular permutations form the backbone of every living matter as we know it and, together with water could be called the "dirty half dozen" of forming and sustaining life, including the growth of plants and animals. This combination of a multitude of such molecules forms the *second* building block.

Let me add one more critical element, light, that is, mainly visible light. It is the *third* building block. Without light, the two first building blocks would not be able to work together and support the growth of life, organic matter, and animals and plants, let alone humans. I do realize that there are life forms on our planet earth that grow and thrive in the absence of light, but when it comes to traditional agriculture for both plants and animals, light is a crucial element.

The *fourth* building block is temperature. Life as we know it does not really thrive in extreme temperatures, such as below 273 K ( $-0.15^{\circ}\text{C}$ ) or above 325 K ( $\sim 52^{\circ}\text{C}$ ). Yes, there are bacteria or even specially adapted types of frogs that are known to grow or survive below 273 K ( $-0.15^{\circ}\text{C}$ ) or even close to temperatures at which water is boiling in volcanic environments. The latter goes for

- Water → H<sub>2</sub>O
- The “appropriate” basic molecules (just the major ones) → O<sub>2</sub>, H<sub>2</sub>, N<sub>2</sub>, C, S, P
- Light → visible wavelengths from approx. 400 nm to 700 nm (possibly 380 nm to 750 nm)
- Temperature → most comfortable range from >273 K to <325 K / 220 K to 370 K is possible

**Figure 1.1** The four building blocks of growth.

bacteria, not the frog! Animals in arctic or Antarctic environments can survive at temperatures as low as 220 K (−53 °C) because they have developed survival strategies, both genetic as well as behavioral. So the range in which life as we know it can exist is probably larger than described here and could range from 220 K (−53 °C) to 370 K (97 °C).

Enough of this excursion into these basics; I just want to make sure that we have the same basic understanding of the topic ahead and accept these definitions of the major required building blocks of water, molecular composition, light, and temperature as baseline for this book. I know that this is rather short and only scratches on the surface, but believe that this is setting the tone of this book appropriately.

Figure 1.1 depicts in a simplified form the four main building blocks for growth and sustenance of life.

### 1.1.2 Some History of Agriculture

In case you know it all already or are typically not interested in history of any kind, including the one that describes agriculture at large, then please skip this section and move on to the next section. Although I do hope that I can convince you to read on through this section.

The drive for survival, which includes searching and finding food and water as well as breathing air, is the most important basic physiological need according to Maslow (1943): “Air, water, and food are metabolic requirements for survival in all animals, including humans. Clothing and shelter provide necessary protection from the elements.”

It can safely be said that since the dawn of time, or since the beginning of animal life in any form, this drive for survival has always existed and has preoccupied all life forms in important ways. Even plants, solidly rooted in the ground, strive for growth and existence by feeding on nutrients in the ground “breathing” oxygen, assimilating carbon dioxide and reaching out for light. Animals, irrespective of whether they are prey or predator, are in constant search of food and water, while breathing air and, for many different reasons, they also need light.

Humans, by most definitions, are predators, although they might be hunted as prey by large carnivores in some parts of the world. Their first and foremost task during all periods of evolution, and to this very day, is to find enough “fuel”

or enough food and water to grow, to survive, to exist, and be able to expand their activities to whatever they have chosen them to be. However, satisfaction of basic physiological needs, or in simpler words, making the body function properly, is still the main driver. Unless we all become robots, this is not likely to change any time soon.

Although debated by some, humans, at least in more recent times, are omnivores (i.e., eating just about anything, from plants to animals and most recently even cheap and crappy food). With some exceptions, every type of food is welcome into the stomachs of human beings. Not surprisingly, exceptions are rather numerous and include people who don't eat certain foods for ethical or religious reasons (e.g., vegetarians, vegans, halal, kosher) or health reasons (e.g., free of lactose, gluten, sugar, salt). I shall discuss this and other related topics in much detail in Part 2, especially in Chapters 5, 8, and 10.

The story goes that human beings started out as predators with opportunistic strategies to obtain food and find water. Hunting was part of this strategy and being able to read and understand surrounding nature intimately was of the utmost importance. Moreover, there was no guaranteed and continued supply for food, especially enough food for all. Community was, and is, important for physiological needs and safety needs escribed by Maslow (1943): "Once a person's physical safety needs are relatively satisfied, their safety needs take precedence and dominate behavior."

### 1.1.3 Eat More and Increase the Likelihood for Survival

There is one more, often overlooked element to this story of the development of mankind, namely those who were able to eat more food and drink more water than others in the community or village—whenever food and water became available—had a better chance to for longevity and longer-term survival than those who were second in line. In actual terms, this simply means that the more you could eat and keep, the fuller your stomach became, the better your chances were that you were still around say in 2 weeks or so, when the next successful hunt was brought in or when you or your friends came across enough berries and other edible plants in your environment.

I used the *village* loosely because those were also times when groups of people, hunters and other members of the tribe, roamed along after game, edible plants, and sources of water in opportunistic ways. Once everything that was within reach was hunted and all the berries were foraged, one had to move on to the next location where game and plants were again abundant. In addition, seasonal variations made life even more difficult and the uncertainty of regular and sustained food and water availability ultimately drove such hunters and gatherers to become more sedentary and start the "business of agriculture"...

Well, maybe not so fast. I wouldn't call it business yet because domestication of a variety of plants, mostly grains as well as animals, happened for reasons of personal survival first. After the last Ice Age some 20,000 years ago, depending on climate and region of the world, animals such as bison, goats, later sheep, and cows were domesticated, first for personal use and probably only much later as a business—goods for trade—for some in ways similar to those that we know today.

Fairly early on in the process of domestication we find dogs, evolving from wolves. It is interesting to note that wolves and humans hunted (and for wolves this is true to this day) in groups or packs, led by males, and were all members of the same family who were friendly to each other but suspicious of outsiders and competed for the same prey. It is likely that out of this common pattern of hunting, domestication of wolves toward dogs happened at a rather early stage, and respective bone finds date back some 12,000 years supporting this (“History of the domestication of animals,” n.d.).

So, what do we have until now? Agriculture, as previously defined, is not a really old activity pursued by humans. However, agriculture in the larger sense of existence of natural resources, plants, and animals, is rather old—arguably as old as plants and animals, and through predator–prey relationships, always made use of each other, although not in organized ways.

#### 1.1.4 Food Can Be Grown and Plants Can Be Bred: What's Next?

Once humans knew how to grow seeds and other plants and once they had mastered domestication of “useful” animals through more or less controlled breeding, it quickly became apparent that food might be prepared in better ways than through hunting and gathering. Apart from preparing food of vegetable or animal origins through any kind of cooking, preservation of food became an increasingly important element. Preserving food by either appropriately storing it or by applying simple preservation methods such as cooking, drying, salting, fuming, or other types of preservations such as cold storage in dug-out cellars became the name of the game.

These methods were created rather early on during the gradual development of humankind and can be linked to the “discovery” of fire, most likely a few hundred thousand years ago, and much later, to the mining of salt from either rock or seawater, and their appropriate application for food preservation. Although in the early days of our history cooking, fuming, drying, and salting dominated food-preservation techniques, many more such preservation methods have been used in more recent centuries as a result of supporting technological developments, scientific discoveries, and the recognition of specific nutritional needs.

Methods such as industrial type of cooling, sugaring, pickling, alkalizing, canning, jellying, curing through fermentation, pasteurization, UHT, sugaring,

vacuum packing, canning, bottling, adding of food additives (artificial or natural), ionizing radiation, pulsed electric or magnetic fields, modified atmosphere, ultra-high pressure, and bio-preservation using specific biota are the most prominent ones in this long list of food-preservation techniques. Additionally, food preservation can be achieved through appropriate so-called hurdle techniques, which are mainly, although not exclusively, composed of smart modulation of pH, water activity, and temperature.

Table 1.1 depicts a typical list of food- and beverage-preservation techniques (not necessarily complete).

**Table 1.1** The major food preservation techniques.

Drying	Oldest documented technology; sun drying as early as 12,000 BC
Cooling	Slowing down microbial growth and reproduction
Freezing	For preservation, processing, and distribution
Boiling	Kills microbes
Heating	Below boiling yet just hot enough to kill microbes
Salting	Draws moisture, reduces water activity
Sugaring	Preserving mainly fruit in antimicrobial syrup
Smoking	Aids drying and reducing water activity
Pickling	Edible antimicrobial liquid either chemical or through fermentation
Alkalinization	Food becomes too alkaline for microbial growth
Canning	Sealing in of foods
Jellying	Solidification, improves water activity
Curing	In general: dehydration to reduce water activity
Fermentation	Replace bad microbes by good ones; creates new products
Pasteurization	See heating
Vacuum packing	Air tight environment: exclusion of oxygen
Food additives	Antimicrobials, antioxidants
Ionizing radiation	Kills microbes (sometimes affects food product)
Pulsed fields: electric/ magnetic	Can destroy bacterial cells
Modified atmosphere	Exclusion/reduction of oxygen
Ultra-high pressure	For preservation of freshness and appearance of food
Bio-preservation	See fermentation
Hurdle technology	Avoid microbial growth through pH and water activity management

### 1.1.5 From Very Old to Rather Recent Food-Preservation Techniques

I do realize that I have jumped ahead quite a bit, but I really want to keep this section on history of food preservation as short as possible. I needed to build the framework for the coexistence, almost cohabitation, of agriculture from its beginnings to this day and the series of important steps toward industrial food and the food industry. Most of the old fire-related preservation techniques, especially cooking and curing through techniques such as smoking, are almost lost in time when trying to put a date on them; others such as industrial cooling can more easily be related to more recent technological achievements such as the invention of the mechanical/electrical fridge, which dates back to the early 20th century. On the other hand, use of ice for cold storage and prolonged preservation dates back to prehistoric times. It was only through mechanization of the creation of cold temperatures for either processing or storing or both, that the food industry could create products such as ice cream, frozen entrees, or freeze-dried soluble coffee on an industrial level.

Anyhow, let me describe a few old food and beverage industries that can be dated back through written records and that have been operational since their creation. The oldest records of a beverage company and that is still manufacturing and selling products to this day is the “Weihestephan Monastery Beer Brewery” (“Klosterbrauerei Weihestephan, n.d.) in Bavaria, Germany. Although founded probably even hundreds of years earlier by monks, the first written and still-preserved records date back to the year 1040. This seems to be the record-holder when it comes to carrying the banner of oldest, and still operational food or beverage company, with almost 1000 years of age! Some of the “middle aged” giant Sequoia trees in the Californian Sierra Nevada were just adolescents during those years.

There are others, such as the “Salumeria Giusti” in Modena, Italy, which dates back to 1605. The mineral water company “Aqua Panna” was founded in Tuscany, Italy, in 1564 and still produces bottled mineral water. I mention these to demonstrate that food is history and history is food; it’s a longstanding relationship and dates back hundreds and even thousands of years, such as to the first traces of wine-making in giant, air dried amphora-like clay vessels in Georgia, South Caucasus, as far back as 8000 years ago.

All this leads to one more surprising, or maybe not so-surprising, observation: beverages, and especially the alcoholic ones, seem to have a far longer history compared to the much-younger (mainly) food companies such as the Nestlé Company, which incidentally commemorated its 150 years of existence in 2016. Most other large or small food companies are younger than Nestlé, with the exception of “Salumeria Giusti.”

So let me focus at the task ahead, namely the role of agriculture in today’s food industry and proceed to the next section that discusses and analyzes the “supplier role” of the agriculture industry for the food industry in more detail.

## 1.2 Agriculture: The Main Supplier to the Food Industry

The section head and its underlying meaning could almost be characterized as a simple and obvious truism; however, it's not as clear-cut as this. The relationship between agriculture and the food industry has not always been an easygoing and trusted one. Let me expand on this. Although it is clear that without agricultural raw materials, both plants and animals, no food or beverage product could ever be made and this is true for both the individual food provider at home and the entire food industry. So, things should be simple and straightforward, yet they are not always so smooth.

In my most recent book *Food Industry Research and Development: A New Approach* (Traitlet, Coleman & Burbridge, 2016), I mentioned the story of so-called single-cell proteins, proteins that were derived from oil—oil that comes from the ground that is. This story begins in the late 1950s and ends the mid-1970s. It is one of the rare examples when the raw material for edible food did not come from the field or an animal off the field but straight out from the deep ground. This mostly happened because the large oil companies felt that they had a surplus of oil that could serve goals other than being fractionated and burned or made into chemicals and could actually feed a growing world population. On the other side of the coin, it was feared that traditional agriculture could not keep up with this growing world population and other, artificial sources would have to be tapped into.

Making sugar from wood, not a typical food source, is possibly another example in which traditional agriculture, farming, and animal husbandry have not worked hand in hand in a supplier–receiver and transformer relationship. Although most of sugar obtained from this source—glucose in a yield of more than 20%—is used to be fermented to ethanol, and in theory, this sugar would, after refining, be good for human consumption if need arises. Needs had arisen in past wars and nobody tells us that it might not happen again. On the other hand, refining such substrates and rendering them safe for human consumption would be so expensive that thus far such sugars from wood, either through chemical or biochemical pathways, were and are exclusively used to generate ethanol.

### 1.2.1 Artificial Ingredients

I do agree that these examples are rather outlandish and rare, and in almost all instances, agriculture really is the main supplier of raw materials to the food industry. I say main, because in the past, food manufacturers sourced quite a number of minor food ingredients from the chemical industry, especially food colors, many food flavors, and to some degree even emulsifiers and stabilizers were of “non-natural” origin. Over the years, the trend moved to the so-called

“nature identical” and then most recently to “all natural” food ingredients. It has been quite a lengthy ride and was almost exclusively initiated and driven by the consumers and consumer organizations. It was, and still is, not an easy feat to find all natural equivalents for all product-critical minor ingredients, such as vibrant and shelf-stable natural food colors for products such as Smarties® or M&Ms®.

Parent organizations and members of the medical and scientific communities feared and suspected that artificial food colors were responsible for some health disorders that may have befallen our kids after consumption of such colored products—although there are no entirely proven and well-established relationships that would point to a clear-cut cause and effect. As always in the world of science, more clinical and similar studies are required to make a clear case. There also appears to be a genetic disposition for such sensitivity to artificial food colors. There is still much debate in the scientific community as to what degree certain artificial food dyes are linked to children’s disorders such as hyperactivity or attention deficits.

Older studies, such as “Artificial Food Colors and Childhood Behavior Disorders” by Silbergeld and Anderson (1982), have found that exclusion of artificial colors from the diet did not demonstrate an important enough beneficial effect. And the article suggests that a genetic basis might be responsible for certain neural responses that should be considered in future studies.

Another more recent scholarly article by Harrington (2015) concluded that certain color additives to food products contribute to hyperactive behavior in children. Further, Kanarek (2011) describes attention deficit disorder (ADHD) as one of the most prevalent behavioral disorders in children. Risk factors are genetic as well as of environmental nature.

I discuss this here not to stir the pot and take a position on the topic but to show that the food industry’s approach to these matters is not always driven by reason but rather by margin considerations, and that the agricultural industry, properly involved and connected early on in these matters, could have helped and solved this issue much earlier. Often, voluntary anticipatory actions are probably the best ways forward to constructively and positively tackle any subject and help everyone concerned to build and maintain trust and mutual respect.

These excursions into topics such as food ingredients and health are just a few examples of the importance of this relationship and will be discussed in the next section and more in depth in Chapters 8 and 10. It is probably the most controversial topics of all: how can and does food influence our health, both in the immediate and in the medium to long-term future.

### 1.2.2 The Main Raw Material Sources

Thus far, I have attempted to describe a few examples—which are the outliers—of the exceptions in which agriculture is not or far detached of being the raw material supplier to the food industry. These represent a minority, a really

small, yet influential share; influential here in the sense that they negatively impact the standing and reputation of the food industry, at least for the chemically derived minor food ingredients of the artificial type. The vast majority of food ingredients, however, stems from agriculture of any kind, plants, animals, and animal derivatives such as dairy products and eggs. Focus on breeding, sustainability, and the economics of plant and animal agriculture will be discussed in Chapters 3 and 4, respectively. Given that water and its availability are key ingredients in *any* form of agriculture, Chapter 2 will discuss this topic in depth.

However, let me introduce these various elements here so that you, the reader, are being prepared to these topics of what is ahead. The simple facts are the following: the major crops such as wheat, sugar beet, maize, corn cob, potatoes, rice, and soy probably represent the vast majority of the total plant agricultural raw material input. The remainder—always on the vegetal side—such as fruits and the minor crops (also called “orphan” crops) make up for the rest. A large proportion of orphan crops, especially, such as coffee and cacao, go towards the food industry, whereas the split of the larger crops between industrial and personal use is more equilibrated. Large food companies such as Nestlé or Mars absorb large percentages of these two orphan crops of up to and around 15% of the total world production each; almost the opposite is true for the use of milk and dairy products.

The more recent numbers from Eurostat show the following picture for the European Union (Eurostat, 2015):

- Cereals (wheat, spelt, barley, grain maize, corn cob mix): 324 million tonnes
- Sugar beet: 128 million tonnes
- Oilseeds (mainly rape seed, turnip rape, sunflower): 24 million tonnes
- Tomatoes: 17 million tonnes
- Carrots: 5.5 million tonnes
- Onions: 6.4 million tonnes
- Fruits: 14 million tonnes
- Grapes: 23 million tonnes
- Olives: 8 million tonnes

### 1.2.3 Milk's the Star

Although all dairy products such as cheese and processed milk and milk powders of any kind are clearly the children of the food industry, the global shares of large food companies in the dairy segment are much smaller, often below 2% or less.

Not wanting to bore you too much, however, here are a few numbers concerning the milk industry from a global perspective (all numbers based on milk from mainly cows and buffalo; FAO, n.d.).

- It is estimated that worldwide milk production rose by an annual 13% between 2002 and 2007.
- It is widely assumed that too much milk may be produced, especially in developed countries.
- Total annual milk production accounted for approximately 700 million metric tons in 2007.
- The largest milk producers in 2007 were: South Asia (mainly India and Pakistan) with 160 billion liters (23% of global production); the European Union (mainly Germany and France) with 150 billion liters (21%); the United States with 85 billion liters (12%); Russia and Ukraine with 70 billion liters (10%); Latin America (mainly Argentina, Brazil, Colombia, and Mexico) with 70 billion liters (10%); China and Japan with 56 billion liters (8%); and New Zealand and Australia with 28 billion liters (4%).

Milk is an important and special ingredient in the overall ingredient mix in the small and large food industry. Typical products derived from milk are butter, cream, cheese, whey proteins at large, any type of milk powder such as nonfat dry milk powder (NDM) or the almost identical skim milk powder (SMP), and a few more applications such as ingredients in ice creams, dairy creamers, and infant formula. Milk and its subproducts are also found in beverages (smoothies, milk shakes, cocoa beverages) as well as in milk chocolate and many culinary recipes for sauces, binders, and simply as taste and texture improvers.

#### 1.2.4 Milk...What Else?

There are, by the way, uses of milk and dairy products that are to be found outside the food and beverage range of products. Milk derivatives can be found in the manufacture of plastics, textile fibers, glues, ethanol, and methanol. Casein-based glues were already known in ancient Egypt but caseinate-based polymers are still used in protective coatings, paper coatings, foams, adhesives, and injection molded items. Caseinates can also be found as surface-active agent in soaps.

Whey and whey proteins can be used as important precursors to be fermented to methane, ethanol, butanol, acetone, organic acids, amino acid, vitamins, a number of polysaccharides, and oils. Much more detailed information on this topic can be found in an excellent article by Audic and colleagues (2003).

In the light of apparent overproduction of milk in many parts of the world and because of much resistance by farmers—not to mention transforming industry and the trade—it would be advisable to look into profitable and useful alternative usages of milk and its derivatives that can help to improve sustainability and gradually reduce dependence on fossil fuels. I do realize that it might be most desirable to reduce milk production, thereby reducing the number of animals and ultimately reducing the carbon dioxide as well as

methane emissions, thereby reducing overall greenhouse gas emissions. However, as long as this is not happening and before much of the surplus of dairy products goes to waste, they may be used for nonfood, alternative applications.

### 1.2.5 Other Excursions from Food

On a similar subject, but in the context of other agricultural raw materials such as corn, sugar beet, or sugar cane, much debate has arisen around the topic of using food raw materials for nonfood applications such as to create ethanol and to some degree methane (mostly from the “less edible” neutral biomass) as well as plastics materials such as poly lactic acid (PLA), all through fermentation. This approach has aroused much public debate, especially questions about having arable land competing for either food or other nonfood applications.

It was speculated that perfectly edible and useful agricultural raw materials such as corn and sugar cane were and are taken out of the food raw material stream, thereby decreasing the amount of food available for human consumption and in turn increasing raw material costs. Although there is some value to this argument, the more prevalent reason to reject this approach is the reduction of land available to grow crops for food. The fact is that countries like Brazil cover a large portion of their mobility needs by substituting gasoline for ethanol, obtained from fermenting cane sugar.

Brazil is the world's second largest producer of ethanol fuel. Brazil and the United States led the industrial production of ethanol fuel in 2014, together accounting for 83.4 percent of the world's production. In 2014 Brazil produced 23.4 billion liters (6.19 billion U.S. liquid gallons), representing 25.2 percent of the world's total ethanol used as fuel” (“Ethanol fuel in Brazil,” n.d.)

Currently there are more than a dozen automakers that offer so-called flexible fuel vehicles in Brazil, which can run on any mixture of E25 (25% ethanol) or E100 (100% ethanol). It is estimated that ethanol amounts to approximately 50% in the fuel mix for vehicles in Brazil.

There would, however be alternative pathways to escape this debate over arable land between food and fuel or plastics. The first one is to use halophytic plants, which are plants that are saltwater resistant and grow on land that is otherwise not fit for growth of regular agricultural material. Thus creating an entirely new stock of available biomass for transformation first to methane and, depending on the plants that are either already available or would need to be developed by breeding, to ethanol in a later stage. I developed a set of ideas as early as 2010 about this and have tried to find investors for this idea. I was unsuccessful.

### 1.2.6 Noncompeting Alternatives

A few years ago, I attempted to get a business going in the area of saltwater-resistant plants, so-called *halophytes*. These could be bred and grown in agriculturally solid and sustainable ways, leading to a noncompeting, side-by-side coexistence of growing food and feed on the one hand and biomass for fuel on the other. I have suggested the following:

#### Halophytes—A New Lifeline

Today's biofuels and bioplastics are mainly derived from plant materials that are either directly competing with the food and/or feedchain such as corn and to some degree sugar cane or grow on lands that could be used for food crops such as switch grass.

It is a fact that large biofuel transformers today exclusively use corn, sugar cane and switch grass as raw materials.

Algae are another alternative and today companies develop special algae, however mainly for the production of specialty lipids or other high added value ingredients.

We can potentially escape this dilemma by using [saltwater-resistant] plants, so called halophytes, as the starting bio mass for further transformation to biofuels.

Underlying are two basic ideas:

- 1) The development, optimization and usage of [saltwater-resistant] plants that serve as biomass to be transformed to either methane or ethanol or both.
- 2) The usage of land with high degrees of salinity, which cannot be used to grow traditional food crops anymore and which can give livelihood and personal wealth to farmers and their families who otherwise would not have a basis for farming and income anymore. In Bangladesh alone, according to a 2010 report from IRIN news (Integrated Regional Information Networks), there are 20 Mio people at risk losing their livelihood due to high soil salinity.

Within the next 50 years, over 20 million people could be displaced and become "climate change refugees," if sea and salinity levels rise in Bangladesh, according to the government's 2009 Bangladesh Climate Change Strategy and Action Plan."

The challenges are complex, yet surmountable and can be summarized as follows:

- Development of appropriate halophytic plants that have optimal agronomic traits such as yield per acre, speed of growth, harvestability, resistance against disease and infestation, overall handling and storage of biomass and fairly short distances to transport such biomass to bio-fuel converters.

- Especially the agronomic development, ideally through selection and fast propagation is the heart of this development and business proposal, resulting in optimized plantlets and seeds that can be brought to farmers in areas with critical farm land conditions such as for example Bangladesh, Bengal and many other borderline lands unsuitable for growing crops around the world.
- The ideal plant should contain both, cellulosic material for fermentation to methane as well as starch/sugar containing fruits that can be used as a basis for transformation to ethanol.
- Initially, the seeds can be made available to farmers through the help of micro credits, NGOs [nongovernmental organizations] and other appropriate organizations until such time that the farmers can develop independence by becoming the important first step in the value chain of biofuel production.

This will, however, just be the starting point for an entire area of other applications such as: applying the developed IP (traits of plants that are responsible for [saltwater] resistance and to some degree drought resistance) to cash crops such as corn, wheat or others but also to plants that are the starting raw materials for the flavor and fragrance industry. (IRIN, 2010; Ministry of Environment and Forests, 2009; H. Traitler, personal communication, August 2010)

In the preceding paragraphs, I mentioned the second alternative; it is not based on traditional agricultural practices but uses the oceans to grow algae in controlled ways. However, to the best of my knowledge, to this day, marine algae are mainly used as raw materials to extract specialty oils of the  $\Omega 3$  polyunsaturated families such as eicosapentanoic acid ( $20:5\Omega 3$ ) or docosahexanoic acid ( $22:6\Omega 3$ ) for nutrition- and health-related applications.

As far as the creation of noncompeting biomass for fermentation to any kind of fuel is concerned, the halophyte pathway appears to be the much more sustainable one, with the additional advantage of giving millions of farmers in adversely affected areas (e.g., flooding, oversalting through irrigation with high salt content water) a future and livelihood for their families. So, this could be an elegant, although neither easy nor fast way, out of this dilemma of competition for arable land.

### 1.3 Agriculture's New Role in Light of Food and Health

Health has become one of the dominating concerns of large parts of the population. I realize that this sounds rather bombastic, but I believe that for many populations in developed countries, this may even be an understatement.

Health and wellness have become an obsessional pastime for many, if not all. There is nothing profoundly wrong with this trend, however, there is probably still much debate what can improve health and how can our good health be sustainably supported both, in the medium and, especially, the long term.

For many, physical activity is the key. For others, it's more the mental activity that counts. For most, however, outspoken or not, it's the combination of both, as the Roman poet Decimus Iunius Juvenalis so famously and appropriately said, *mens sana in corpore sano* (MSICS; "a healthy mind in a healthy body"). Most likely every one of us would agree to this; however, we may have different approaches as to how to best achieve such a balanced status. It is my firm belief that food and drinks do not yet play the role that they not only deserve but also actually need to play in getting to the so desirable MSICS status! But why is that so? Well, simply because we still have the mentality of "everyday low prices" and "greed is cool" when it comes to shopping for our food.

It has been mentioned that there is a negative correlation between the low-price performance of a food discounter and the size and luxury of cars parked in the parking lot of such discounters: the lower the food prices, the more expensive the cars parked in front. I admit that it is a simplistic view and does not happen everywhere, but I have observed this many times. It is also clear that people need to be able to afford food for their own and their families' daily needs and often typical salaries are just not sufficient to purchase valuable food—valuable in a nutritional sense that is. There is still too much disparity between nutritious and inherently healthy costly food versus so called "cheap calories"; affordable for those who have little or need to use their government food stamps for their food purchases.

It's not easy to break out of this vicious circle, and I discuss this topic here because agriculture has its fair share in this and has an important role to play. Let us get back to the desire and need of achieving and maintaining good health through means of physical activity and mental training paired with the right food—the right nutrition for everyone. Everyone means two things here: first, the largest possible number, ideally the totality of the population to be fed properly, and secondly, the recognition that not everyone is equal to everyone else and a good degree of nutritional personalization would be the ideal end state. Part 2 of this book will discuss this apparent dilemma and great challenge in much more detail.

Suffice it to say that with today's means finding solutions to this riddle will be difficult. That does not hinder us to at least try and think it through and propose possible solutions to this problem of healthy versus unhealthy, more valuable food versus cheap calories, high costs of food versus affordability, implication of food in the health cycle and especially in the larger healthcare business environment, and last but not least, how to convince everyone involved in this field to agree to commonly acceptable solutions. Again, agriculture has a major role to play in this.

### 1.3.1 Decades of Food Safety Rules and Regulations

It's a simple fact that food, and in turn, ingredients and raw materials that go into the manufacture and production of food and beverage products have been and still are increasingly regulated and scrutinized from all angles, not least of all food safety and health-related aspects. This is a good thing and should not be reversed by any means. It is maybe interesting to observe that the number of food and food ingredients rules and regulations have increased pretty much at the same pace as analytical sciences have developed to being able to detect smaller and smaller amounts of just about anything, relevant or not.

Organic analytical techniques have made quantum leaps of improvement, even more so since the full integration of IT qualification and quantification techniques for the better part of 30 or so years. Signal-to-noise detection has vastly improved, and all analytical techniques have participated in this improvement. This has gone hand in hand with being able to discover more and more food-related hazards since the 1960s.

Let me quote from an excellent report published by the European Commission (2007):

The first EU food hygiene rules, which were adopted in 1964, were limited to requirements for fresh meat. Over the decades, however, further hygiene legislation was developed and implemented for other food groups, including eggs, milk products, poultry meat, fishery products and game meat. (p. 16)

Today, food regulations cover all food groups, all food and beverage ingredients, regardless of origin. Again, it is a good thing for the safety of consumers to have an appropriate number of rules and regulations in place, yet one negative result of this situation is the abuse of these rules for political or financial gain. Scare tactics are often used and consumers are always in the middle of any such debate. I do not want to go into much further detail, but I can say with conviction that I have seen that abuse exists and that it does not necessarily help the cause of protecting the consumer in the best possible ways, and at the same time, leaving room for nutrition and health-related improvements in the food and beverage industry.

The story of the "evolution" of the mentioned food hygiene rules and food health and safety issues could have been written by Agatha Christie or Stephen King but can rather be found in the report of the European Commission (2007). Let me go through the decades as well as topics.

The 1960s saw the first important push into the food safety issues of that decade such as:

- Salmonella in eggs
- *Escherichia coli* (*E. coli*) in undercooked meat

- *Clostridium botulinum* in improperly canned foods
- *Listeria monocytogenes* in unpasteurized milk (boiling up importantly in the mid- to late 1980s)
- *Staphylococcus aureus* in ham
- *Trichinella spiralis* in undercooked pork
- Hepatitis A virus in shellfish

Much of this was simply that more modern food processing, preserving, packaging, storing, and transporting food technologies were especially developed and improved during these years.

The 1970s saw an important push toward mastering safety issues and alerting the food and government communities to better protect consumers. It was also during those years that the public began to link unhealthy food products and unhealthy eating with disease and premature death. The important issues of those years were (and still are, by the way and this is valid for the list of the 1960s too!):

- Pesticides and their residual levels
- Food additives
- Flavorings
- Contaminants and their maximum levels

The main food safety issues of the 1980s were the following (with a continued close eye on all of the preceding, too):

- Salmonella outbreaks
- Cases of botulism
- Bovine spongiform encephalopathy (BSE)

The biggest food safety–related topic during the 1990s was probably the large BSE outbreak in the United Kingdom at the end of that decade.

- BSE
- Dioxins

Lastly, in this context, the topic of genetically modified organisms (GMOs) was, and still is, the most prominent and most hotly debated topic of that decade. The major push, unfortunately came from the agricultural industry, which wanted to push apparent solutions to the consumers, without really explaining what it was all about and what benefit the consumers would take from GMOs.

Yet another big issue discussed and dissected in many was the pushback from regulatory authorities to the inflation of health-related claims for food and some of its ingredients. This caught many in the food industry, who had spent millions to support such soft health claims, really by surprise.

Maybe the most important topic of debate during that decade was the push toward proper information, traceability, and education and training for all

members of the food and beverage industry. This holds true to this day and is probably the best way forward toward innovative, safe and healthy foods and beverages (European Commission, 2007).

### 1.3.2 More Rules: What Do We Do?

One can confidently say that the world of food, food ingredients, and processes became more complicated in the last 50 years, probably even more so in the last quarter of a century. Over the years I could observe different answers to this increased complication of the world of food.

I don't want to point any fingers at any food company in particular, but the typical patterns of response to crisis were also to be found here. I am referring to Elizabeth Kübler Ross's (1969) response pattern to grief: denial, anger, bargaining, depression, and acceptance.

The individual descriptions of these five stages, "translated" to the tightening regulatory situation in the food industry could be the following.

- 1) **Denial:** The first reaction is often denial by refusing the premise. In this stage companies, and especially middle management, might believe that the newly proposed rule is somehow mistaken, going far too far, or is simply wrong, and they might cling to a false, preferable reality.
- 2) **Anger:** When the company and its management, middle and higher, recognize that denial cannot continue, they become frustrated, especially at "proximate individuals"—both inside and outside the company—especially at representatives from the regulatory authority. Typical company responses could be: "Why our industry, why especially our company? It's not fair! How could this happen to us? Who is to blame? Why could this happen and why were we not better prepared? Our people really sleep and didn't earlier pick up, what was coming our way?"
- 3) **Bargaining:** The third stage involves the hope that the company might just be able to avoid hardship. Usually, the negotiation for more lenient judgment is made in exchange for a promise of developing better and healthier products for all consumers.
- 4) **Depression:** Here we are probably deviating most from the original grief management concept and language. In typical food companies, such state of depression might simply be expressed by announcing yet another cost-cutting exercise, stopping projects, or worst, letting people go.
- 5) **Acceptance:** "It's going to be okay; we can't fight it, we cannot get away by not complying, so we may as well prepare for it and even do better than our competitors. We are going to be the really good guys!"

I agree that maybe not all five steps can be seen in all difficult, crisis-like situations, but I personally have seen and heard many of these elements and arguments in numerous cases over my many years in the food industry.

The best and most efficient answer to the increasingly difficult regulatory environment in the food and beverage industry is simply to be ahead of the game. Sounds easy but it's not. The consequences of not complying with regulatory requirements are pretty dire and can lead to really dramatic situations for the company, even leading to its demise. Therefore, and despite the humanly understandable reactions as described in the five stages, the straightforward reaction should always be compliance.

However, being ahead of the game is far better. How can my company—any company—be ahead of the game? Well there are two possible approaches, which do not exclude each other and are probably most efficiently applied in complementary fashion.

Here's the first approach: become an active and constructively contributing member of important food regulation associations, thereby helping to drive the agenda together with the other representatives, such as governments and consumer organizations. Thereby, your company is not only well aware what is being discussed and soon to be cast in a new rule but you can also hear and experience “what is cooking” and how this might affect your company in the future. The mantra is constructive input and output and collaboration; it must never be controversy, although debates may be heated.

My second approach to make life simpler and more enjoyable for you and your company: simplify. What do I mean by this? Well, simple (no pun intended): Demystify and simplify the list of ingredients that are needed to make a specific product; keep it proverbially stupidly simple and more easy to understand for the consumer and at the same time reduce the number of possible regulatory touch points. I do realize that this is not an easy feat and especially not easy for well-established products in your portfolio. But it can definitely be applied to any new product development in the future and I shall discuss this topic in later chapters.

Reality, however is a slightly different one: the world of food, for many reasons, has become more complex and more complicated, and agriculture and the production of agricultural raw materials for the food industry has an increasingly important partnership role to play.

### 1.3.3 Raw Materials and Processes Become More Sophisticated

For those readers who do not like the word *sophisticated*, I could offer alternatives such as fancy, complex, functional, traceable, sustainable, healthy, nutritional, affordable, tasty, safe, or simply a combination of all of these. I believe you see, where I am going with this. And all this, in my eyes, applies to the development, growth, harvesting, storage, and distribution of agricultural raw materials but also to the various unit operations happening in the food and beverage industry. Typical such operations are procurement, inbound supply chain, manufacturing, packaging, storage, and outbound supply chain. It would

be a fair comment to say that this is slightly oversimplified as the entire value chain for both partners—agriculture and the food industry—is far more complex and is comprised of many more elements and activities happening in both areas. So let me focus on the agricultural raw materials first and discuss and analyze some of the most important aspects.

This discussion has much to do with today's expectations that many or most consumers have when it comes to food, *their* food that is! Consumers have become sophisticated, too. They have sophisticated expectations with regard to food and beverages.

When looking into the public discourse regarding food in more detail, the consumer, or rather the majority of consumers with the economic possibilities to afford food, has a certain set of expectations and requirements. I do not speak about developed countries compared with less developed ones because the boundaries are not between countries any more when it comes to being able to buy appropriate food for oneself and one's family but they have fault lines between the various segments within one country.

Let me briefly discuss the United States as an example because it might be the most striking one, given the fact that overall, on the grounds of most economic factors, the United States is a rather rich country. That said, many people do not have enough financial means to buy food for them and their families.

Let me "bore" you with a few numbers. When looking back over a period of 40 years, the number of people had received food stamps to purchase their daily food amounted to approximately 21 million in 1975 and rose to an all-time high of 47.6 million in 2013. It has since then slightly decreased and in July of 2016 stood at 43.6 million. This means that slightly more than 14% of the U.S. population, or every seventh person, receives food stamps and, at least in part, lives on support from the government.

The average monthly value of food stamps per person was around \$17 versus \$127 in 2015 or about seven times higher (SNAP, 2017; Trivisonno, 2017). Part of the increase in value is simply explained by monetary inflation over a period of 40 years and part of it might be based on authorities' recognition and acceptance of the fact that proteins simply cost more than bulk carbohydrates. When looking into the consumer index average annual numbers, we see an increase of a factor of 4 during these same 40 years (Consumer Price Index, 2017). The larger increase can hopefully really be attributed to a better nutrient mix in food that can be purchased with such food stamps.

These numbers are not only striking but they also prove that, as far as access to and availability of nutritious and healthy and affordable food is concerned, there are no country distinctions, such as developed or developing, and it is more important to look into societies and even communities within such societies in much more detail.

Let me briefly come back to the already mentioned requirements for modern food and how these take roots, literally, in the preceding agricultural practices,

directions, and strategies and how they can and must feed into the food industry but especially into the consumers' mouths and bodies.

Modern food, if there is such a thing, is supposed to be healthy and nutritious. Modern agricultural output in terms of crops and other semi-finished products demands efficiency and stability and preservation during transport and distribution to the various manufacturing sites. Although the wine industry has more or less voluntarily reduced the output of grapes per vine or per square feet or meter, to enhance quality of the end product, all other branches of agriculture have, as far as I am aware, gone in the exact opposite direction.

Chapter 3 will expansively discuss, analyze, and scrutinize modern plant agriculture, including topics such as modern breeding methods and the economic and societal dimensions and importance of the major food crops as well as so-called orphan crops. Chapter 4 has at its core the agriculture of animals, especially the theme of animal proteins of the future and the sustainability of such proteins in an increasingly complex humanity. Chapters 5 and 10 will discuss and analyze topics such as food trends, new (not novel) foods and the availability of healthy and nutritious food of today and discuss possible future scenarios.

## 1.4 Most Likely Drivers for Change in the Agriculture Industry

Change is palpable, yet change is feared as previously described in Kübler-Ross's "angst" scenarios and subsequent reactions. However, even without notice, change does and will happen in all domains of life, including the world of agriculture. At the risk of repeating what has been said elsewhere and even before in this book, let me list the main drivers for change—subtle and gradual or more revolutionary.

As we know by now and for quite some time, the world population is not only at a constant but also fast paced growth. Although the estimated total world population accounted for "just" 1 billion persons, it took until 1927 to reach double that amount. However, it only took less than half a century to double that number again to 4 billion in 1974, and it is taking even less time to almost reach 8 billion, which by all estimates should happen around 2020. These are just numbers, but behind them are people of all genders, age, and race, and they all need food and water. However, our planet has not become bigger, at least not that anyone noticed. Yes, some have said that by submitting every single person in this world to the same living space conditions as people in Hong Kong, the entire world population might fit in the state of Texas. Yet their needs as far as food and water go still need to be fulfilled through modern agricultural techniques and usage of arable land for a growing number of people in our world.

I do not want to get in this debate whether the world is “overpopulated” or just “badly distributed”; after all we are talking about human beings and their rights to live a good life and be able to feed themselves and their families in the best possible and most healthful and nutritious ways. I do insist on “most healthful and nutritious” because I truly believe that this a basic human right and is not negotiable. I do realize that this may sound utopian, or even naïve to some, but I truly believe in this mantra, which was one of the major reasons I worked almost my entire professional life in the area of food.

Let's not get into politics, but just state a few simple facts: world population stands at close to 7.5 billion in 2016; arable land, useable to grow crops or graze cattle, has not really increased, and yet agricultural practices have been devised over the years that have improved crop output per acre, have in some instances been able to switch to more drought-resistant plants, have, in part thanks to a warming climate in many parts of our world, made it possible that in moderate zones, two harvests of rape seed oil can be grown now in central Europe. The latter is of course also made possible because of the abundance of water in these areas.

Other, much warmer and much dryer areas, such as the Mediterranean can often not even get to one full crop. Although temperatures and abundance of light maybe just perfect, water is missing in the equation. Some of my best friends are avocado and citrus growers in Santa Barbara and San Luis Obispo counties of California. Much has been written and said about the ongoing severe drought in most parts of California, and although we as private citizens do our fair and honest share in the mandatory water-conservation efforts, even saving 20% in areas outside agricultural use of water, is just a drop in the entire equation. It is estimated that agriculture in California uses up to 90% of all water resources in the state, and so 20% of the remaining 10% only account for a 2% overall reduction of water usage.

To come back to my avocado- and citrus-grower friends, I know for a fact that they are really low on water, so much so that they had to stump a good portion of their avocado trees and, on top of this are just beginning to see the onslaught of the “Huanglongbing” or greening disease caused by the Asian citrus psyllid, which is just arriving at their doorstep. So, the conditions are not the best for these farmers, and there are many, many like them, with no or very little water and bugs that may potentially wipe out entire industries, which is something that has already partly happened in Florida. The topic has become so hot that an article in the Bloomberg News (Perez, 2015) mentioned that oranges in Florida are possibly doomed unless ways can be found to stop the citrus psyllid. Both scientists and governments need to collaborate on this important issue.

I do not want to end this chapter with a flood of lamentations but rather lay the foundations for what is to come in the following chapters and sketch in a broad stroke the topics that are paramount to better understanding the topic of

megatrends in food and agriculture by highlighting themes such as technology, water use, and nutrition. The ultimate goal is always the same: to optimize and modernize these elements in such a way that the people in this world can have better lives through an improved access to affordable, safe, healthy, and nutritious food, and yes, it should taste good, too.

## 1.5 Summary and Major Learning

Food and agriculture are truly important topics to discuss and especially in a book like this one that attempts to combine these two areas in ways that help to better understand not only the megatrends but also the interaction and interdependence of these.

The following topics were discussed and analyzed in this chapter.

- When trying to define what agriculture means and stands for, a recurring pattern can be observed with keywords such as: *using natural resources, produce commodities to maintain life, arable farming, agronomy, horticulture, crops, fibers, forest products, livestock, animal husbandry*, and last but not least, the link to the *food industry, preparation and marketing of resulting products and food*.
- Nature's four building blocks to support life and also agriculture in any form are: water; molecular permutations of oxygen, hydrogen, nitrogen, carbon, sulfur, and phosphorus; visible light of 400 to 700 nm, possibly 380 to 750 nm; and appropriate temperature range from more than 273 K to less than 325 K, possibly from 220 to 370 K.
- Some history of agriculture was discussed, and from Maslow's theory of human motivation, it was quoted that air, water, and food are metabolic requirements for survival in all animals, including humans. This drive for survival is probably as old as animals and humans on this planet.
- When humans were hunter-and-gatherers, opportunistic strategies toward agriculture were the rule and humans ate what they could come across—animals, seeds, berries, and roots. Those who could eat more whenever food was available had a better chance of survival, given that the next successful hunt or forage was probably several days or even longer out.
- Later on, the opportunistic approach to agriculture gave way to a more planned approach, both in the area of domestication of animals and in organized farming of crops.
- Once there was some know-how and technology available to breed domesticated animals for food and to grow and harvest crops, approaches had to be devised to render agricultural output stable, at least for short periods of time. Some of the oldest such preservation technologies are drying, salting, and fermenting.

- Fermentation led to one of the oldest industrial food products and related companies, the oldest of which was founded in the year 1040 and still produces beer to this day under the same name “Weihenstephan.” Many of the longest existing—and still operating—companies today are food and beverage companies, although the majority much younger being only 50 to 150 years old.
- The role of agriculture as the main raw material supplier to the food industry was introduced and discussed, as was the attempt to create food (especially proteins) from other than agricultural sources, such as oil.
- Other examples of food and beverage raw materials were discussed, such as artificial colors, flavors, and texturizing agents. Some of them are still used to this day.
- Main agricultural raw material sources for the food industry were introduced and discussed, and they account for the vast majority, especially when it comes to volumes.
- Although the food industry acquires large portions of some specialty crops, such as coffee and cacao, the use of milk is more widespread, and the largest food companies today purchase 2% or less of the total global milk production.
- It was also discussed that milk was, and is, used to manufacture products other than food, such as plastics, textile fibers, glues, ethanol, and methanol.
- Other deviations of food raw materials towards nonfood applications are sugar and other fermentable carbohydrates, which are used to manufacture ethanol for transportation and polylactic acid for packaging purposes.
- It was briefly discussed that side-streaming edible carbohydrates toward nonfood application can have a true or “perceived” price impact because competition for arable farmland. A solution of which would be the further development and smart applications of halophytic crops that would grow in agronomical worthwhile speed and yield on overly salty or seawater-flooded low-elevation, otherwise unusable, farmlands.
- The important topic of agriculture’s new or newly defined role in the light of the relationship of food and health was introduced and discussed. The old Roman concept of a healthy mind in a healthy body was mentioned, and in today’s everyday low prices for food state-of-mind it is difficult to appropriately adhere to this mantra.
- The all-important topic of food safety and food regulations was discussed as was the food industry’s reaction, which includes the agriculture industry as well. This reaction has not always been an enthusiastic one and historically has a shaky path toward fully embracing necessary and appropriate rules and regulations.
- Food and especially food processing has become more sophisticated, much more complex and complicated. This has, in part, led to the distinction into “cheap, bad calories” and “good, valuable calories,” with a rather clear distinction when it comes to paying the price for these.

- Today's consumer societies' boundaries are not any longer country boundaries and do not follow the distinction between developed and developing nations, but the fault lines are within one and the same country, irrespective of its position in the affluence scale. It was discussed that in the United States every seventh person lives on food stamps.
- Lastly, this introductory and tone-setting chapter honed in on the question of most likely drivers for change in the agriculture industry. Population growth, paralleled by the fact that arable land has not really increased lately, more sustainable innovation has to come from this industry. Increasing efficiency of water usage in any shape and form and being able to fight and eradicate pandemic plant as well as animal diseases are key topics; however, they are not the only ones.

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