TECHNOLOGY
WATCH REPORT

Smart Food

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Parc de Recerca UAB

Universitat Autònoma de Barcelona

eurecat Centre Tecnològic de Catalunya

Associació Àmbit B30

TECHNOLOGY WATCH REPORT
Smart Food

Autors
Roser Salvat Jofresa, UAB Research Park.
Marta Tort Xirau, UAB Office of Patent Valuation.
With the collaboration of: Hafsa El Briyak Ereddam (UAB PUE - University Business Program) and the IRTA Technology Watch Unit.

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UAB Research Park
Av. de Can Domènech s/n - Eureka Building - UAB Campus
08193 Bellaterra (Cerdanyola del Vallès) Barcelona · Spain
www.hubb30.cat

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1
Overview of innovation and tendencies in Smart Food

The term "Smart Food" is used to refer to foods which, through the application of technologies, preserve food safety, improve their nutritional benefits and healthy effect, better adapting to user needs and preferences.

Manufacturer investments in technology are a key factor

Investments in facilities and technology for process automation are a key competitive factor in the food and beverage production market. It is expected that the **European market for facilities** for the production and packaging of food and beverages will reach 19,900 million Euros in 2022, driven by considerable demand for machinery in final application segments.

"Growing consumer awareness about safety, quality and sustainability drives new solutions"

In this regard, in the future robotics, artificial intelligence and management control software are expected to play an even greater role in all areas from food **processing** to its **packaging**. It is expected that an important number of food processors will digitalise their production plants over the next few years. This is a large volume industry with small profit margins and the eruption of new technologies could imply increased efficiency directly related to competitiveness. In addition to saving time and money, the Internet of Things (IoT) will also put an emphasis on staff and data safety.

It is also expected that the offers of technically advanced manufacturers will progressively focus on **container sustainability**. Without compromising nutrients, innovations strive for simpler containers and the reduction of plastic waste.

Although the constant investments made by this industry in technological innovations are a key differentiating factor associated with market growth, growing consumer awareness about **safety, quality and sustainability** is also driving food and beverage producers, transformers and distributors to offer alternative, more effective and newer solutions.

The population is increasingly aware of the type of foods and beverages they consume, their incidence on food-borne **diseases**, other syndromes and complaints, and in short, their impact on **health and well-being**. Little a little the criterion of "from farm to fork" is gaining importance and, as a result, the demands for food safety and quality connect all participants in the food supply value chain: production, processing, packaging, distribution, storage and at-home preparation.

Globalisation has created safety gaps in the food supply chain

Globalization and the demand for novel and exotic food has increased **food safety** concerns, especially in a world with major differences in national regulations. Globalisation has not only increased import and export activities, but has also created safety concerns for the food supply chain.

The Frost & Sullivan report (2017) "Opportunity in Global Food Safety Diagnostics Market" indicates, using the FDA as a source, that around 15% of all food consumed in the United

States is imported and that this has led to an increased level of contamination of mycotoxins and pesticide residues in the food supply chain. Apart from **adulteration, other incidents** may also occur as a result of inadequate follow-up of microbial contamination, inability to trace products and ingredients because of the complex supply chain, and labelling related errors.

Safety solutions imposed by the agricultural industry

The acquisition of raw materials and food ingredients from various suppliers has become standard practice and the large distances travelled by some food products increase the risks of storage and transport. This means that in the **agricultural** industry safety solutions are related to the need to **manage a changing global social and economic environment** as well as its impact on the demand for safe agricultural production on a world-wide level, but this is also a question of resource efficiency in agricultural and food production driven by the growing need to improve **efficiency** and **profitability**.

"The digitalisation of food safety is an important driving force behind innovation"

The criteria of **food safety**, in short, are imposed in line with and in relation to various factors: food fraud susceptibility; regulatory requirements; the progressive industry culture of quality and risk management; training of the staff in the value chain; practices for the external evaluation of impacts and risks; optimisation of supply chains; social responsibility and, finally, investment in new technologies.

In this context of growing awareness and training, it is probable that in the ecosystem of food production and processing safety will be less dependent on archaic manual methods for data recording and analysis.

Governmental, industrial and academic organisations generate **growing volumes of data related** to food safety, including for example outbreaks of food transmission and molecular epidemiology... all of which is extremely complex and difficult to process with conventional methods.

Under the umbrella of multiple, diversified, large data banks, **the digitalisation of food safety** has become an important driving force behind innovations to prevent, detect, identify the source, isolate or eliminate various food contaminants and their processing environments throughout the supply chain.

Increased demand for food safety technologies

Over the last few years there has been an increase in the demand for profitable technologies enabling follow-up and sharing of information about food production and products. The efficiency of proactive control of expired or ill-treated food products, their traceability and alerts and corrective actions throughout the value chain has been related, among others, with the following **technologies**:

- bar codes and RFID
- sensors and chips
- microarray systems
- characterisation techniques (X-rays, Ultra Violet, Infra Red)
- advanced diagnostic kits (single domain antibodies, bacteriophages, PCR)

- robotics and automation of supports related to diagnostic kits
- software solutions
- applications for mobile devices and smartphones for real time follow-up
- cloud computing and cloud-based solutions.
- software as a service (SaaS)

The market for food safety diagnostics is valued at more than 7,000 M $

Frost & Sullivan (2017) in "Opportunity in Global Food Safety Diagnostics Market" point out that process automation, software-integrated diagnostics, rapid diagnostics, and advanced sensor equipment to obtain faster on-site results are future emerging trends in the **food safety diagnostics market** which in 2016 generated income to the value of more than 7,000 million dollars world-wide.

Technology adoption in the food safety diagnostics space has been increasing rapidly during the past few years with for instance, technologies such as bioluminescence, biochips and biosensors. Regarding contaminant agents, this marker is segmented into microbial pathogens (primarily bacteria); viruses; environmental toxins; genetically modified organisms (GMOs); food allergens and adulterants; residues of drugs and agricultural chemicals.

The next generation technologies include AI, blockchain, PoC, printed electronics, thermosonication and printed biosensors

The report by Frost & Sullivan (2018) "Technologies Enabling Food Safety" considers, however, that the **emerging technologies** with probable impact over the next five years are:

- Artificial intelligence (AI)
- Blockchain
- Point-of-care devices (PoC)
- Printed electronics
- Thermosonication and UHPS
- Synthetic biology

Outstanding among next generation technologies are AI, blockchain, PoC, printed electronics, thermosonication and printed biosensors:

- **Artificial intelligence** is revolutionising the food industry not only in regard to risk and safety, but also for the supply of raw materials, classification and storage of products, among others. Successful implementation of AI demands considerable technology readiness not only within the organization, but also for associated stakeholders. Furthermore, practical application of the technology, combined with cost, performance and user acceptance continue to pose challenges in the wider adoption of AI.
- **Blockchain** implementation will strengthen food safety infrastructure considerably due to its impact on curtailing the problem of food contamination at the root. With Blockchain, incidents of frauds will be easier to investigate due to the availability of a database related to the food item's production and supply chain. Blockchain solutions

are currently in their infancy and lack of proven use cases acts as a challenge for blockchain deployments globally.

- Point-of-care (PoC) food safety **devices** can guarantee timely intervention in the event of contamination during operations to reduce wastage in the retail chain. And now with growing health awareness amongst general population, consumers can use these devices for instance to check the safety of restaurant foods, packaged foods, or marketed foods. Even though PoC devices are already present in the market, future expectations are for lab-on chip based hand-held devices and IoT-connected devices.
- **Printed electronics** plays a vital role in developing connected flexible components such as smart labels used for IoT applications. Advancements in printed electronics are poised to enhance food and beverage consumption safety for consumers through integration of different types of sensors and indicators.
- **Thermosonication and UHPH** are two techniques which are used, to varying degrees, for inactivation of enzymes and microbial growth. Their non-invasive, non-destructive, rapid and precise nature ensures safety and reliability, affecting longer preservation times and a reduction in additives after treatment.
- **Synthetic Biology** is an emerging technology that enables safer and healthier food as result of the powerful combination of various disciplines such as biology, design, engineering and information technology. Synthetic biology techniques will be ideal for designing crops and foods that are resistant to diseases.

Some of the emerging technologies from other industries will have a decisive influence

It is expected that some of the emerging technologies from other industries will also have a decisive influence on the future of the global food and beverages sector: biosensors, genomics, enzyme technology, Big Data, 3D printing and packaging.

- The rapid advances in **biosensor** technologies and their convergence with Big Data platforms are expected to improve global food safety while at the same time providing new platforms for more precise food testing. They will also probably affect the food packaging industry.
- Unlike other technologies that will have a visible impact in the short term, **genomics** has more probability of a significant impact on global markets in the long term, influencing the substantial increase of world production of food with modified genetic traits.
- It is probable that the advances in **enzyme technology** will be driven by the greater use of genetic engineering platforms to improve the processing, extraction, yield and quality of a wide range of food products and beverages.
- **Big Data** platforms will have wide impact on various technological platforms for the use of **emerging sequencing tools** to improve global food safety in the near future.
- It is probable that **3D printing** technologies will simplify clean, efficient printing of home-cooked food as well as gourmet products. The technological convergence

between Big Data and robotics platforms will also contribute to increased development of innovations in 3D printing.

The successful deployment of these technologies undoubtedly requires collaboration efforts between the various interest groups of the sector value chain networks of the sector.

Evolving demands will drive advances in packaging technologies

Furthermore, greater emphasis is being placed on sustainable and safe **packaging** solutions that extend the shelf life of products. The evolving demands of consumers drive rapid advances in technologies packaging with the following **emerging tendencies**:

- environment-friendly containers
- smart container technologies
- nanotechnological containers
- use of hybrid materials
- use of bio-materials such as bio-plastics
- active packaging systems
- edible packaging.

"Growth of functional foods in industrialised societies"

Growth of functional foods in industrialised societies

For some years there has been scientific evidence of the relationship between food and health, particularly in regard to cardiovascular diseases, some type of cancer and other degenerative diseases. In industrialised societies, where a large part of the population have no problem meeting minimum nutritional needs, there is more and more demand for functional foods with the sensorial attributes of traditional foods, but which provide **health benefits or reduce the risk** of suffering diseases.

In this context it is important to distinguish between functional foods, nutraceutics and medical foods.

Differences between the medical foods, functional foods and nutraceutics

Factor	Functional foods	Dietary supplements	Medical foods
Foreseen use	Improve the general health and well-being, reduce the risk of specific diseases or minimise the effects of other health problems	Provide supplementary doses of desirable nutrients	Satisfy the special nutritional requirements derived from a disease
Treatment	Preventive, with non-specific support	Preventive, for an identified problem	Therapeutic

Administration mode	Ingested orally as a solid or liquid food product	Mainly ingested as tablets, capsules, or liquid forms	Ingested orally or enterically in the form of powder, liquid or capsules and tablets
Classical examples	Oatmeal, fortified orange juice	Vitamin and mineral capsules	Glucerna, Nutrini

The **range of functional** products available on the market has increased dramatically. There are multiple possibilities for the production of functional foods; among others, they can be based on:

- the incorporation of ingredients -in general of natural origin- with biological activity into a conventional food
- the elimination of unwanted constituents
- the modification of certain constituents
- increasing the concentration of a naturally present component with beneficial effects on health.

The market offers, among others, foods with a high content in:

- certain fatty acids or sterols
- bioactive peptides
- antioxidants
- soy proteins
- prebiotic carbohydrates
- products enriched with minerals or vitamins
- products fermented using probiotic bacteria.

The European Regulation on nutritional declarations and the healthy properties of foods constitutes an important advance in the regulation of the advertising and labelling of these foods, as it establishes the rules to be followed by the food industry to indicate whether a food contains certain healthy properties. These regulations are of obligatory application in each Member State with an important role being played by the European Food Safety Authority (EFSA). On a state level, the Spanish Agency for Food Safety and Nutrition (AESAN) plays a key role in assessing the scientific bases sustaining allegations, as well as establishing "nutritional profiles".

It is absolutely necessary to advance in personalised nutrition

In addition to continuing research into the molecular mechanisms of the effects of nutrition on health, the future will entail specific ongoing studies of the interest to health of components and ingredients of foods and other positive effects on health of the consumption of functional foods. In this regard advances in the study of the **interaction between genetic factors and nutrition** are absolutely necessary.

The final endpoint of nutritional genomics, nutrigenomics and nutrigenetics is to design a **personalised diet to prevent or treat diseases** by studying individual responses to certain diets as a function of specific variations in the genome.

Consumer tendencies that drive the demand for personalised diets include health and well-being, weight control, sports and physical condition. Strategic associations with the healthcare sector and the interaction between various technological innovations ensure support for the growth of freedom and personalised nutrition markets.

The tendency for "Freedom Food" is on the rise

But consumer driven food tendencies reinforce the search for foods and beverages that are healthier, organic and personalised and encouraged by the convergence of technologies from other areas. This context uses the term "**freedom foods**" to refer to products that are not only safe, but also green, healthy and ethical.

"It is absolutely necessary to advance in personalised nutrition"

Safe:

- Safe design
- Without risk of disease
- Avoids chemical derivatives
- Use of safer solvents, or solvent-free
- Traceable

Healthy:

- Minimal use of unhealthy food additives
- Inclusion of value-added functional ingredients
- Dietary food supplements
- Portion-controlled serving sizes

Green:

- Degradable after product use
- Renewable feed stock
- Minimal by-products
- Energy efficient
- Maximum pollutant monitoring during the production process

Ethical:

- Vegetarian; Vegan
- Kosher
- Halal
- Grass-fed livestock
- Fair Trade.

The Millennials or generation Y demand **food without unwanted attributes**. The values of healthy nutrition and other factors such as allergic reactions and religious and cultural differences increase the demand for more expensive foods, but which consumers are more and

more willing to pay for. Free foods include products that are **alcohol, gluten and lactic-free and without any genetically modified ingredients** (GMOs), as well as fair trade, kosher and halal products. According to Frost & Sullivan (2018) "Freedom Foods and Personalised Nutrition: Market Overview; Challenges and Opportunities", the global market for these foods was worth more than 4.6 trillion dollars in 2017.

This market still has a **number of challenges**, particularly in terms of flavour, texture and shorter shelf life. It is expected that research will continue to overcome these challenges, which will support the demand and, thus, the market growth.

With various descriptions on what constitutes a healthy diet, there is currently no one-size-fits-all approach to healthy nutrition, but there seems to be an unstoppable tendency to embrace tradition, **reincorporating practices and ingredients of close proximity**.

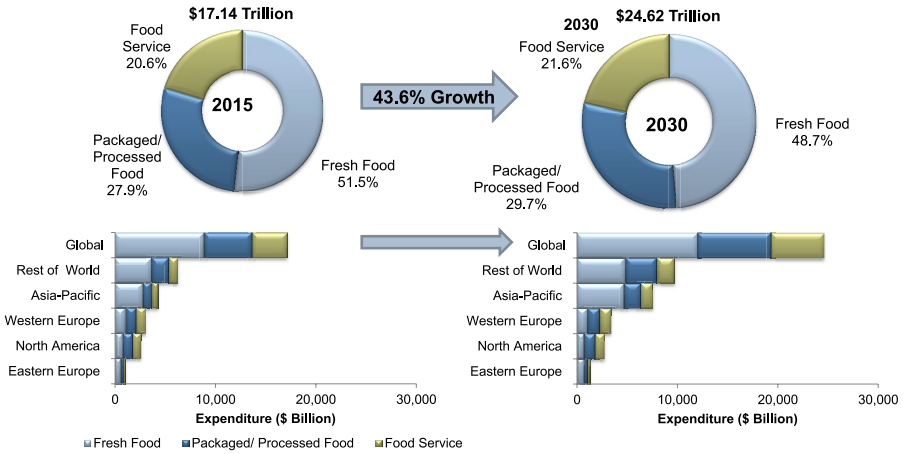
The report by the Institute for the Future of the Bill and Melinda Gates Foundation (20198) "Good Food is good business. Opportunities driving the future of affordable nutrition" forecast that by 2030 the definitions of food safety will not refer to the immediacy, but to **long term** concepts, and encourage recognition of the **richness of the knowledge** in traditional foods throughout the world.

"Towards the criteria for affordable food"

Large food companies with advanced R&D capabilities are well positioned to help build the scientific evidence base around traditional diets and how they deliver important micronutrients. These methods of scientific inquiry can also be applied to discover entirely new foods and techniques that could impact the health and affordability of food. Embracing traditional food wisdom will **require a different approach to trade secrets** and intellectual property.

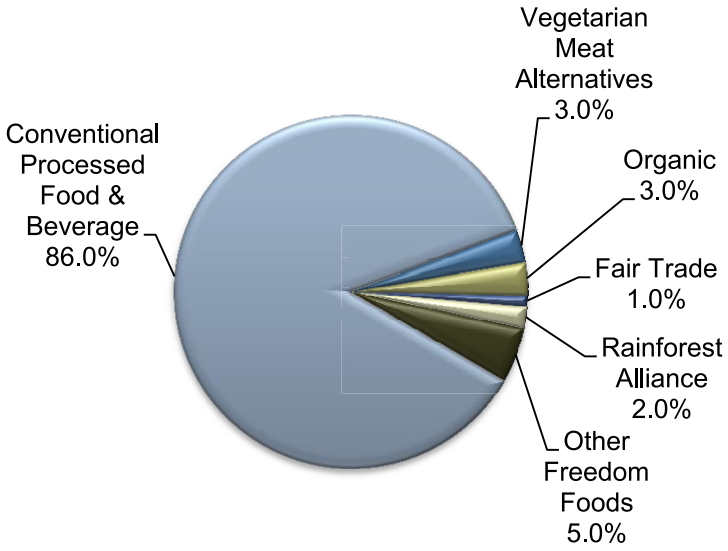
2
Smart Food Key infographics

2.1. Food & Beverage Market: Consumer Expenditure by Primary Demand Channels and Region, Global, 2015–2030



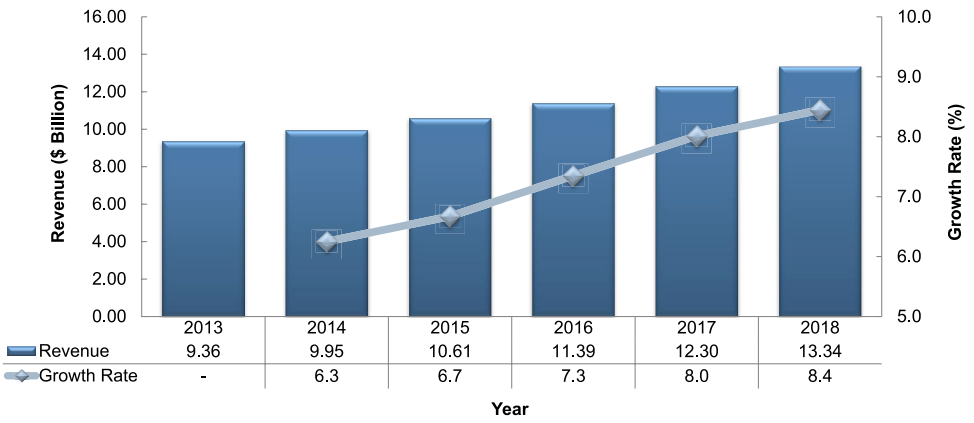
Source: Frost & Sullivan (2016). Digital Transformation in the Global Food & Agriculture Market

2.2. Processed Food & Beverage Market: Freedom Food



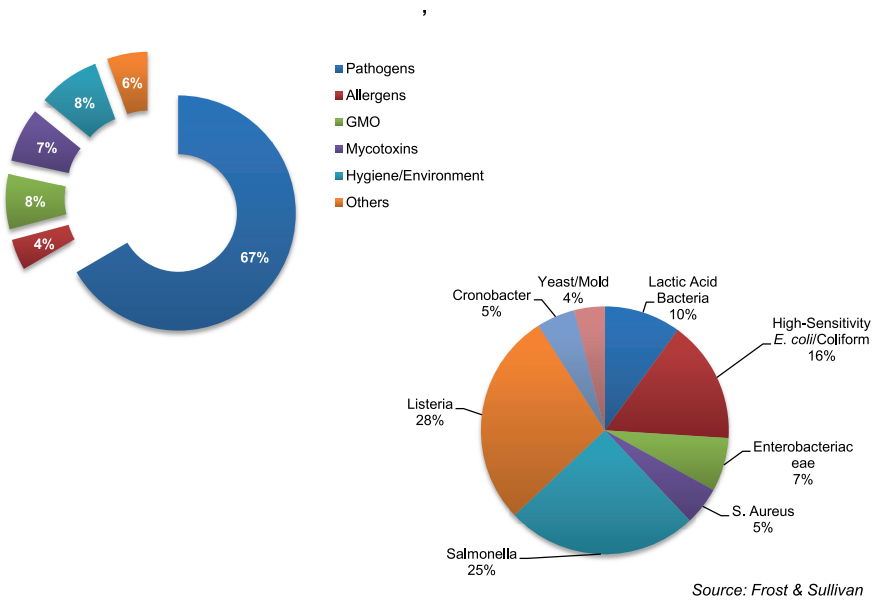
Source: Frost & Sullivan (2018). Agriculture and Nutrition Opportunity Engine Series — Freedom Foods and Personalised Nutrition: Market Overview, Challenges, and Opportunities.

2.3. Medical Foods Market: Revenue Forecast, Global, 2013–2018



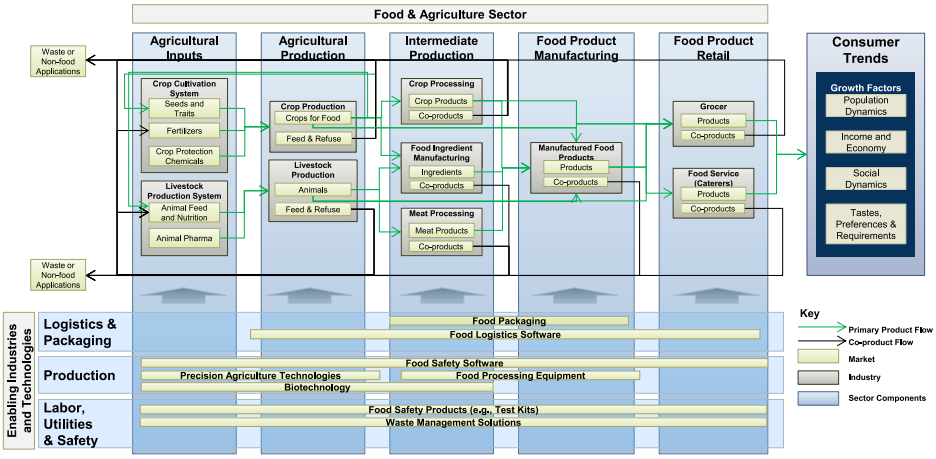
Source: Frost & Sullivan (2014). Global Medical Foods Market

2.4. Food Safety Testing Market: Revenue Forecast, Global, 2016– 2026



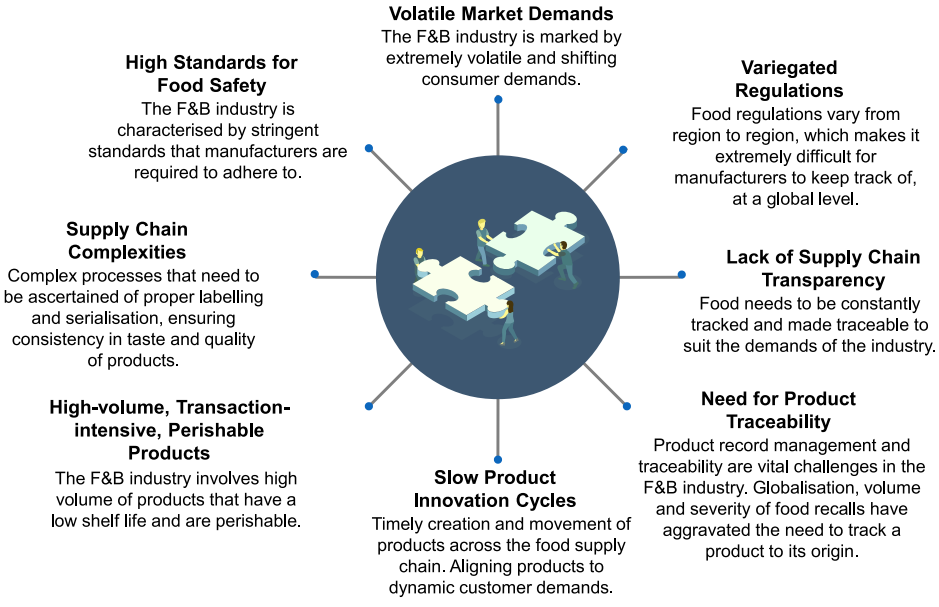
Source: Frost & Sullivan (2017). Breakthrough Technologies Enabling Food Safety in the Dairy Industry

2.5. Food & Agriculture: Value Chain



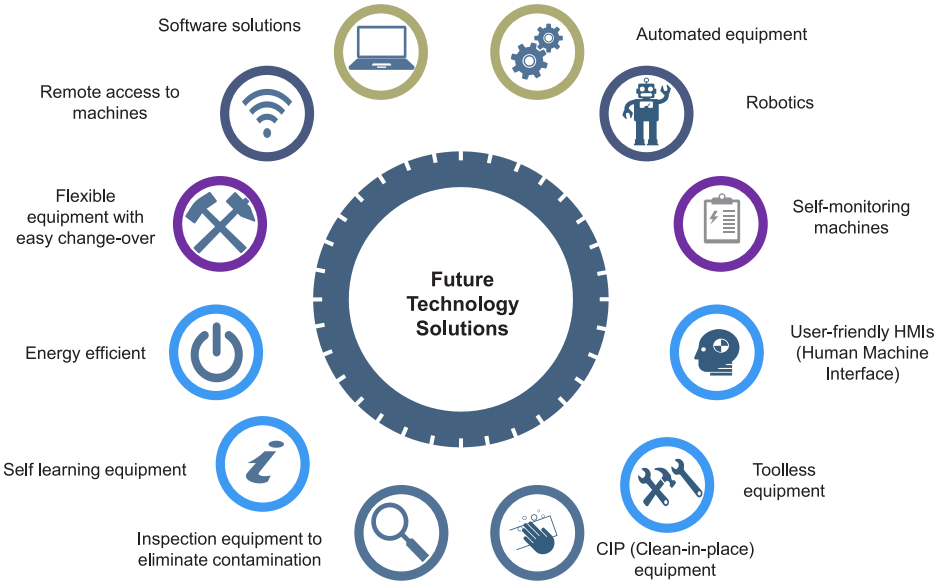
Source: Frost & Sullivan (2016). Digital Transformation in the Global Food & Agriculture Market

2.6. Food & Beverage Industry Challenges



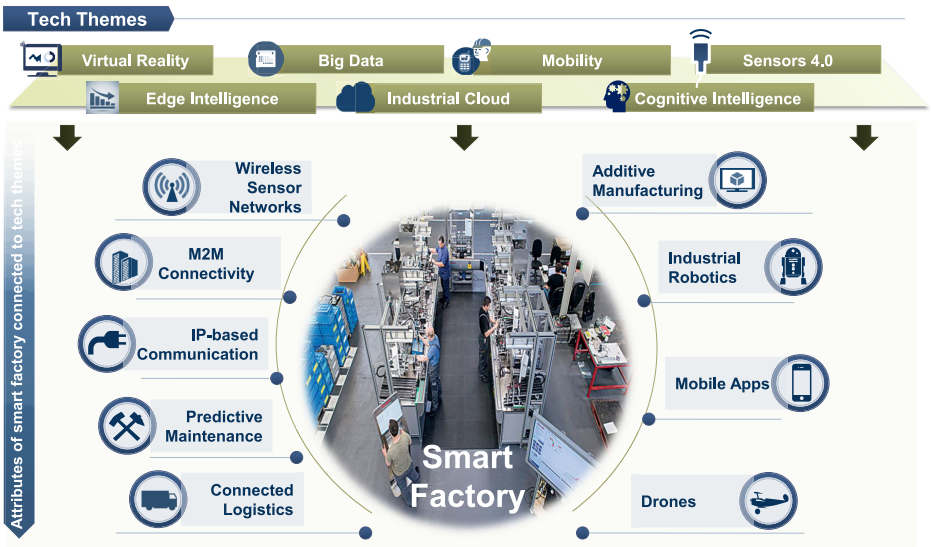
Source: Frost & Sullivan (2018). Food & Beverages 4.0

2.7. Smart Factory: Equipment Innovations



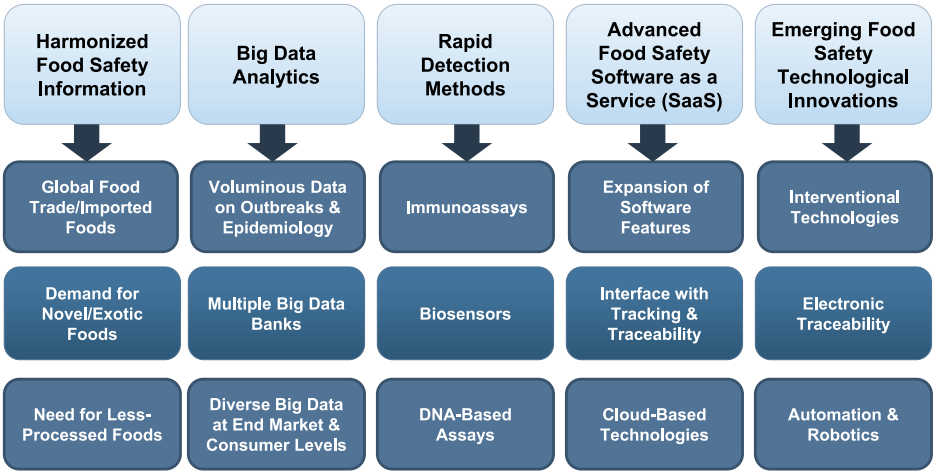
Source: Frost & Sullivan (2018). Global Food and Beverages Processing and Packaging Equipment Market, Forecast to 2022

2.8. Smart Factory: Key Attributes



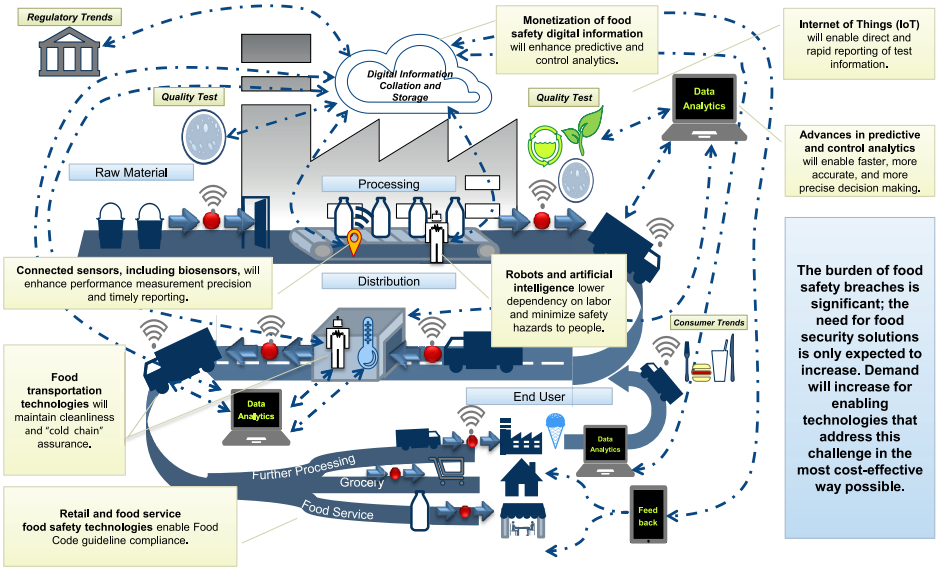
Source: Frost & Sullivan (2018). Food & Beverages 4.0, 2018

2.9. Digital Transformation: Food & Agriculture



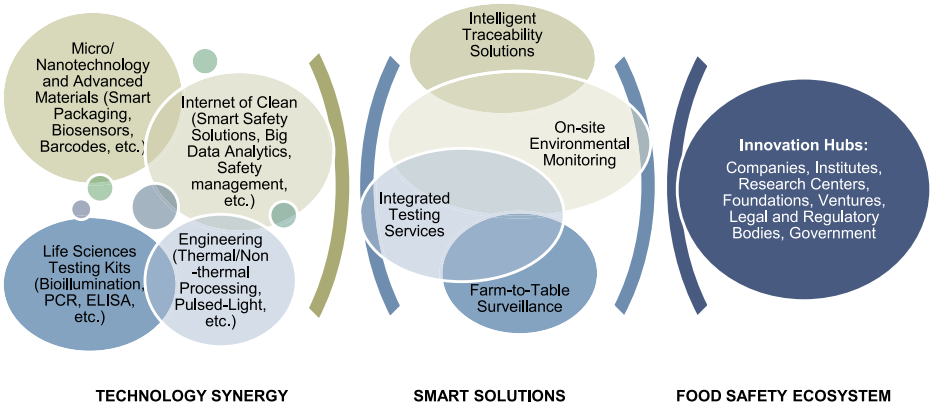
Source: Frost & Sullivan (2016). Digital Transformation in the Global Food & Agriculture Market

2.10. Smart Factory: Digital Transformation of Safety



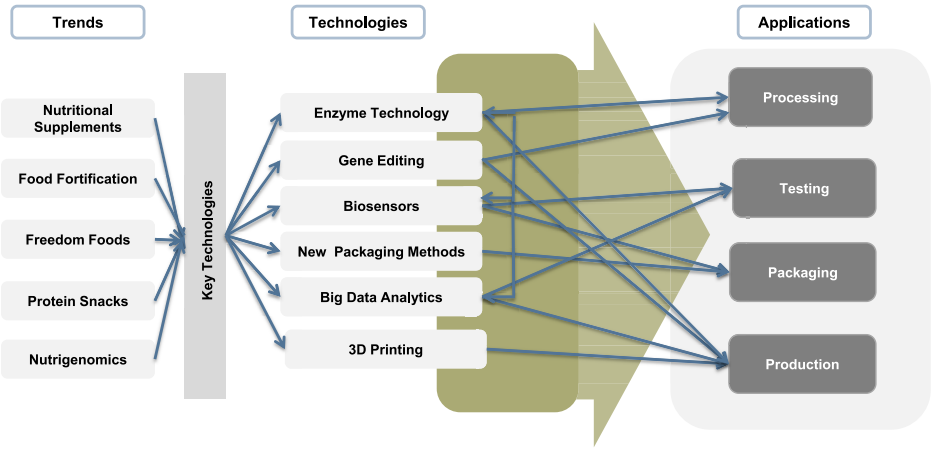
Source: Frost & Sullivan (2016). Digital Transformation in the Global Food & Agriculture Market

2.11. Smart Factory: Safety Solutions



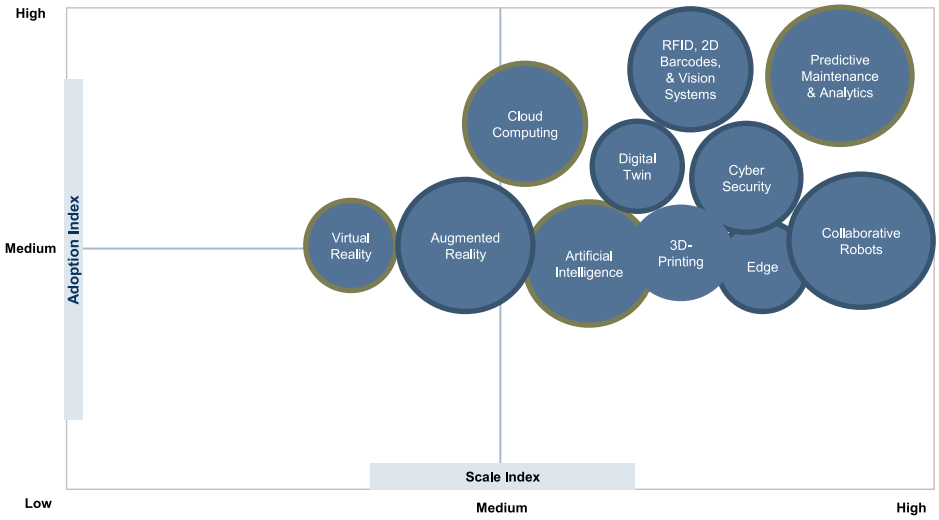
Source: Frost & Sullivan (2017). Breakthrough Technologies Enabling Food Safety in the Dairy Industry

2.12. Food & Beverage Industry: Mapping of Trends, Technologies and Applications



Source: Frost & Sullivan (2016). Technologies Impacting the Future of Food and Beverage Sector (TechVision)

2.13. IIoT in Food & Beverages Industry: Technological Hotspots

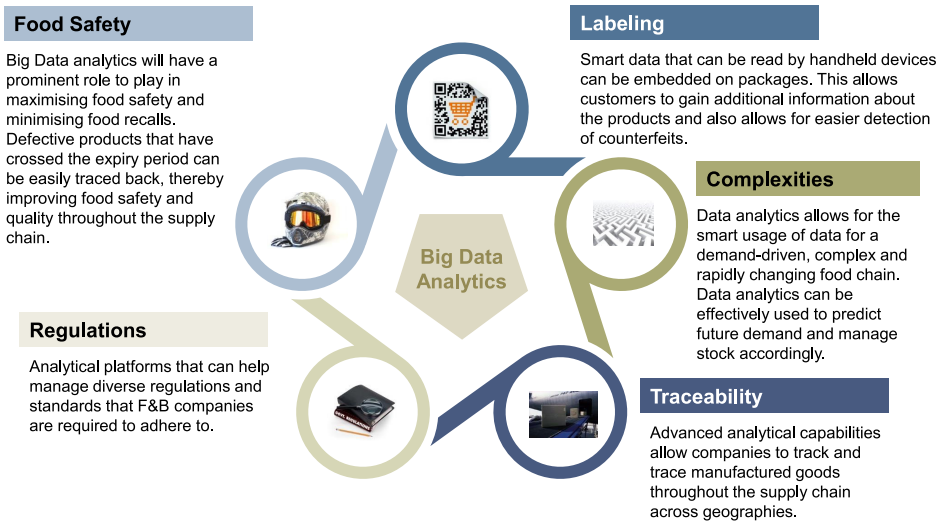


Source: Frost & Sullivan (2018). Food & Beverages 4.0

2.14. Food Safety in Dairy Industry: Intelligent Solutions, Global, 2017-2027

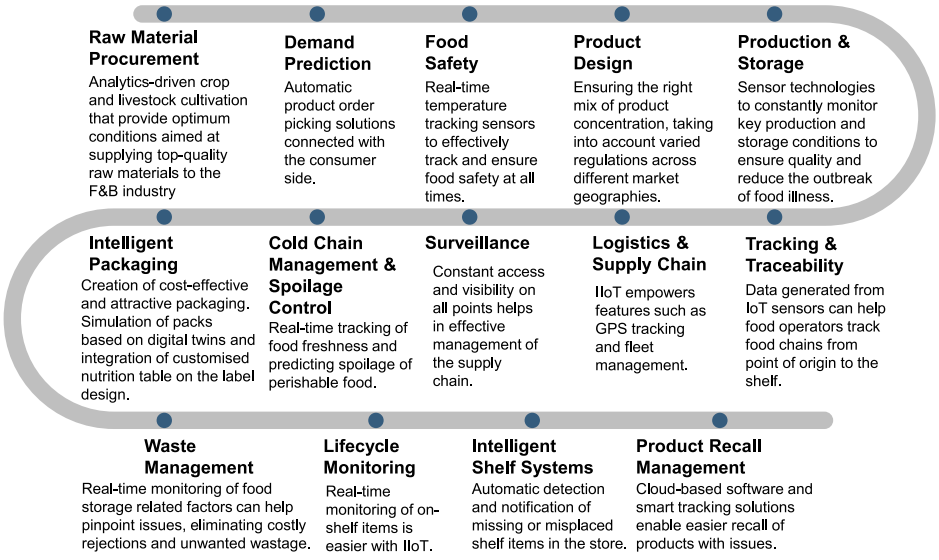
Source: Frost & Sullivan (2017). Breakthrough Technologies Enabling Food Safety in the Dairy Industry.

2.15. Food & Beverage Manufacturing: Big Data Analytics



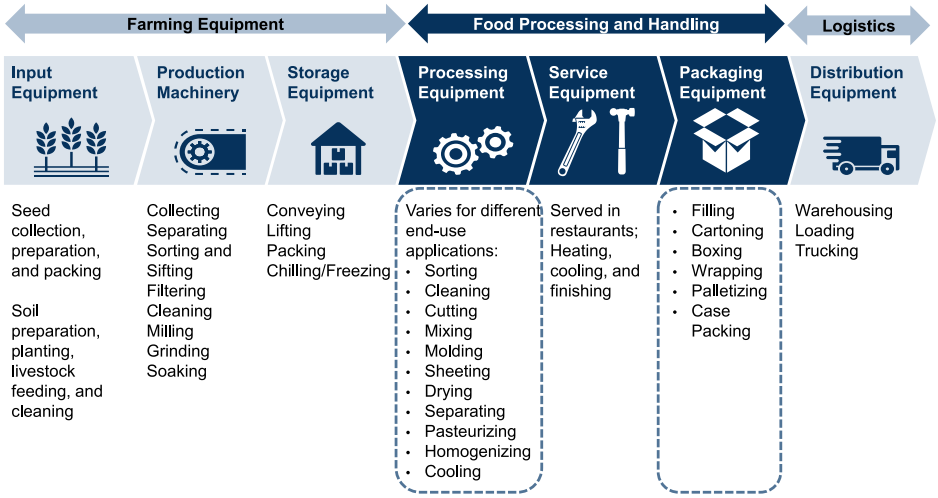
Source: Frost & Sullivan (2018). Food & Beverages 4.0

2.16. Food & Beverage Supply Chain: IIoT Key Areas



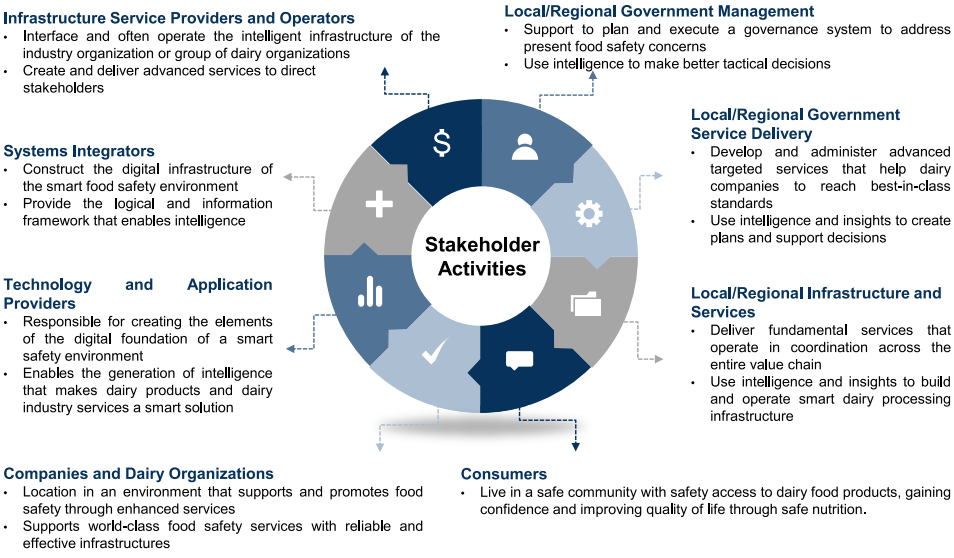
Source: Frost & Sullivan (2018). Food & Beverages 4.0

2.17. Food & Beverage: Processing and Packaging within the Value Chain



Source: Frost & Sullivan (2018). Global Food and Beverages Processing and Packaging Equipment Market, Forecast to 2022

2.18. Stakeholders in Food Safety Value Chain



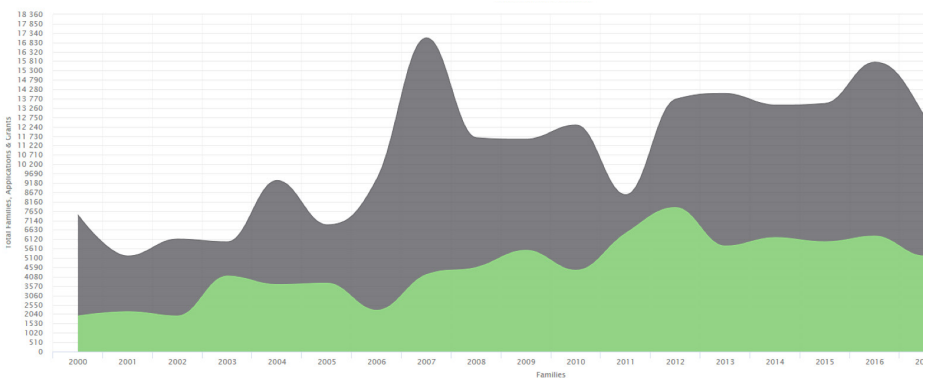
Source: Frost & Sullivan (2017). Breakthrough Technologies Enabling Food Safety in the Dairy Industry.

3
Patent analysis

We refer to Smart Food to describe foods that improve their nutritional contribution and healthy effect, preserve food safety and better adapt to consumer preferences and needs through the application of technologies.
The patent analysis for this concept or area was dominated by the inclusion of the following areas of knowledge: **Functional Foods; Genetic engineering for foods; Artificial intelligence in the food industry** and, finally, **Food packaging**.

3.1. Evolution of patents applied for and granted

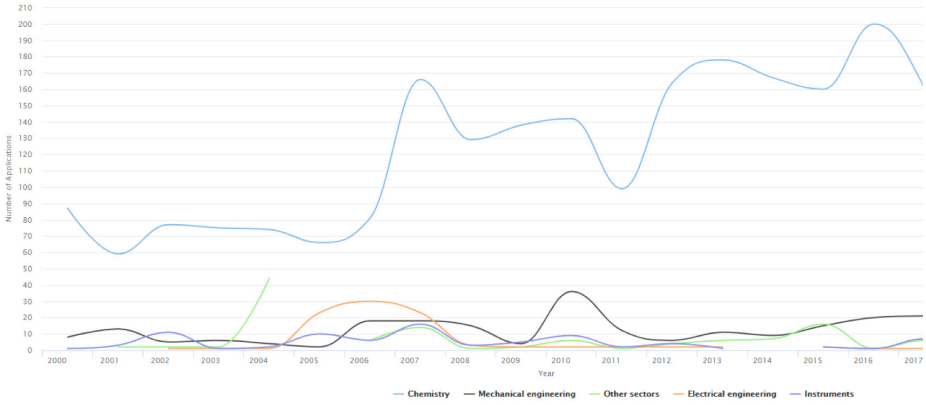
The analysis of patents applied for and granted enables us to understand the **growth tendency** in the area of Smart food over the last two decades. At the same time it shows that the proportion of applications filed that were finally **granted** was **49.5%.**



Source: PatBase. March 2019 Query

3.2. Technological sector of the patents applied for

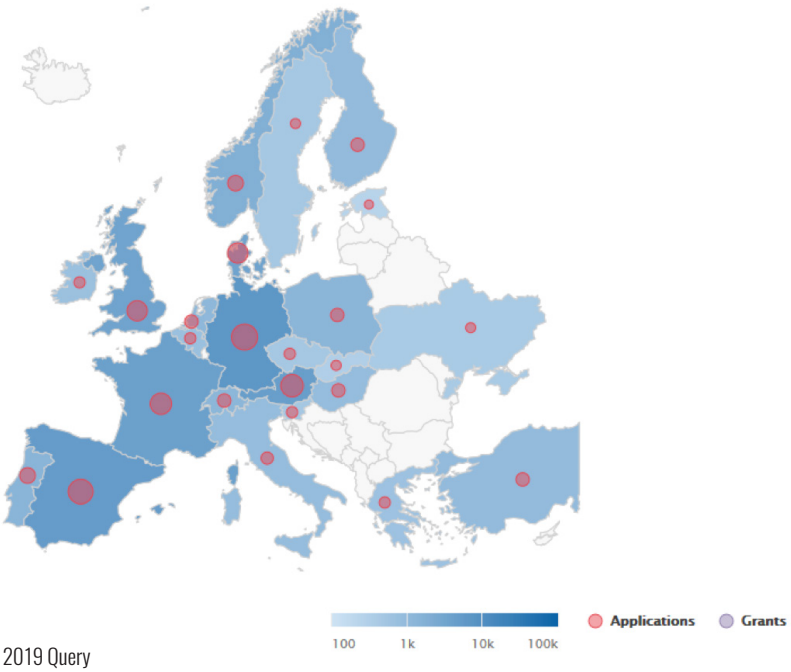
Over the last 20 years, the technologies more involved in the patents applied for in the field of smart food belong to the following fields: chemistry; mechanical engineering; instruments; electrical engineering and, finally, "other fields".



Source: PatBase. March 2019 Query

3.3. Territorial location of patents: Europe is in first place among the continent where most patents are applied for

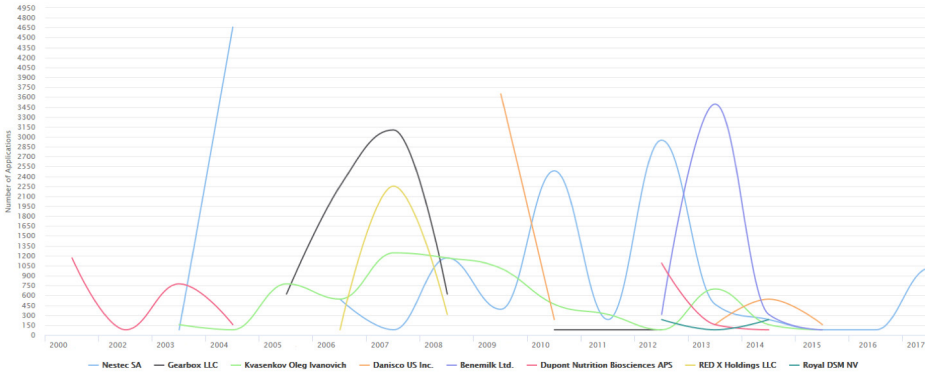
Europe is the continent where most smart food patents are applied for. Within the European Union, as shown on the map, the countries with most patent applications are, in descending order, **Germany**, Spain, Austria, France and England.



Source: PatBase. March 2019 Query

3.4. Most active patent applicants over the last 20 years

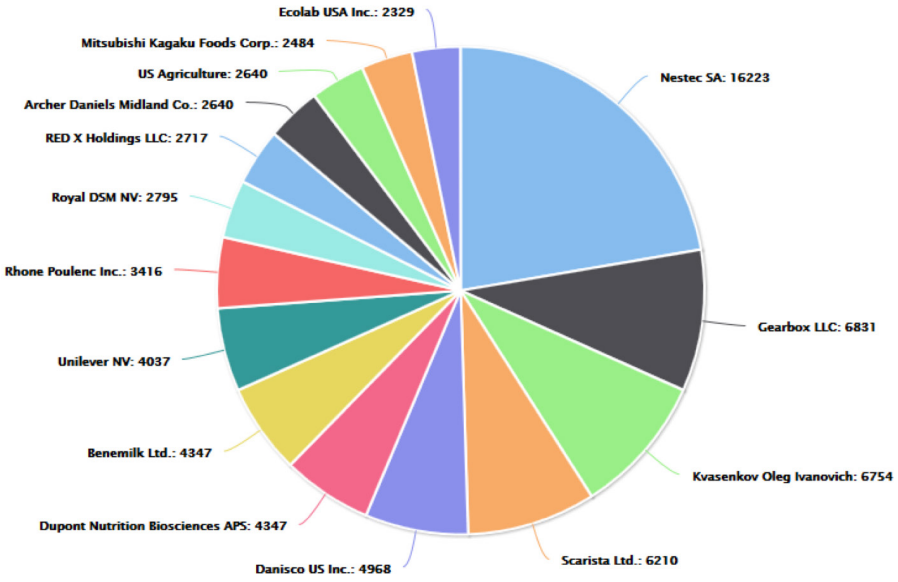
The graph below shows the eight most active organisations in patent applications over the last 20 years, as well as which time periods these applications were concentrated in. Outstanding, among others, are **Nestec SA**; Christian Hansen A/S; Dupont Nutrition Bioscience and Ecolab.



Source: PatBase. March 2019 Query

3.5. Who applies for most patents, the most active applicants

The fifteen most active **bodies** (companies, institutions or people) filing patent applications, including the **number of applications** for each one are shown below.



Source: PatBase. March 2019 Query

3.6. Keywords attributed to patents in this field

The main keywords associated with patent applications in the field of study are: processing method; composition, assorted ingredients; heat, and condition of the ingredient.

Source: PatBase. March 2019 Query

3.7. METHODOLOGICAL APPENDIX

The information provided in the "Patent analysis" section refers to the study performed on a sample of **281,299 patent applications** in the area of Smart Food related to **functional foods; food packaging**; chemical and genetic **engineering** in foods, and **Artificial intelligence** in the food industry.

The study was focused on global patent activity over the last 20 years, with emphasis on Europe.

113.094	**51.308**	**281.299**	**357.135**
Patent family	Family of patents granted	Applications	Publications
Total number of families in this set of results	Total number of families with publications granted with this set of results	Applications with this result	Publications within this result

Source: PatBase. March 2019 Query

The criterion used for the query of this report was the **maximum scope** in the field in order not to impose any limit and include all results relative to the field. Among the words alluding to Smart Food, the most **active fields** are "functional foods" and "food processing".

On the other hand, the **field with least activity** during the last two decades was "artificial intelligence in the food industry". It was interpreted that this occurred for three reasons: 1) Because artificial intelligence applied to food science and nutrition is not as active as in the case of telecommunications, transports, life sciences or safety (report WIPO IA 2019). 2) Because in spite of the evidence of tendency changes in this area, significant results can only be obtained by centring the analysis only in these areas and more recent years. 3) Because in Europe computer programmes (algorithms) in themselves are excluded from patentability with the exception of inventions with applications of algorithms to technical problems.

Patent documents are classified in different **international classification systems**; the most often used being the International Patent Classification (**IPC**). Pursuant to this nomenclature, obtaining the sample for this report considered the inclusion of the following indexes:

- A23L3/00: Preservation of foods or foodstuffs, in general, e.g. pasteurising, sterilising, specially adapted for foods or foodstuffs (preserving foods or foodstuffs in association with packaging.
- G01N 33/02: Investigating or analysing materials by food.
- A23L5/00: Preparation or treatment of foods or foodstuffs, in general; Food or foodstuffs obtained thereby; Materials therefor (preservation thereof in general
- A23L19/00: Products from fruits or vegetables; Preparation or treatment thereof.

- B65D81/34: Containers for packaging foodstuffs intended to be cooked or heated within the package
- A23L33/00: Modifying nutritive qualities of foods; Dietetic products; Preparation or treatment thereof.
- B65D77/00: Packages formed by enclosing articles or materials in preformed containers, e.g. boxes, cartons, sacks or bags
- A23B: Soil working in agriculture or forestry; parts, details, or accessories of agricultural machines or implements, in general
- A23C: Dairy products, e.g. milk, butter, cheese; milk or cheese substitutes; making thereof.
- A23J: Protein compositions for foodstuffs; working-up proteins for foodstuffs; phosphatide compositions for foodstuffs.
- A23L: Foods, foodstuffs, or non-alcoholic beverages, not covered by subclasses a21d or a23b-a23j; their preparation or treatment, e.g. cooking, modification of nutritive qualities, physical treatment; preservation of foods or foodstuffs, in general
- A01H: New plants or processes for obtaining them; plant reproduction by tissue culture techniques
- A01J: Manufacture of dairy products (preservation, pasteurisation, sterilisation of milk products a23; for chemical matters, see subclass a23c)
- A23V2002/00: Food compositions, function of food ingredients or processes for food or foodstuffs
- B65D81/00: Containers, packaging elements, or packages, for contents presenting particular transport or storage problems, or adapted to be used for non-packaging purposes after removal of contents
- A23P10/00: Shaping or working of foodstuffs characterised by the products
- A23P20/00: Coating of foodstuffs; Coatings therefor; Making laminated, multi-layered, stuffed or hollow foodstuffs
- A23P30/00: Shaping or working of foodstuffs characterised by the process or apparatus (A23P10/00, A23P20/00 take precedence)
- G06F3/00: Input arrangements for transferring data to be processed into a form capable of being handled by the computer; Output arrangements for transferring data from processing unit to output unit, e.g. interface arrangements.
- G06N5/00: Computer systems using knowledge-based models
- G06F16/00: Information retrieval; Database structures therefor; File system structures therefor.

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