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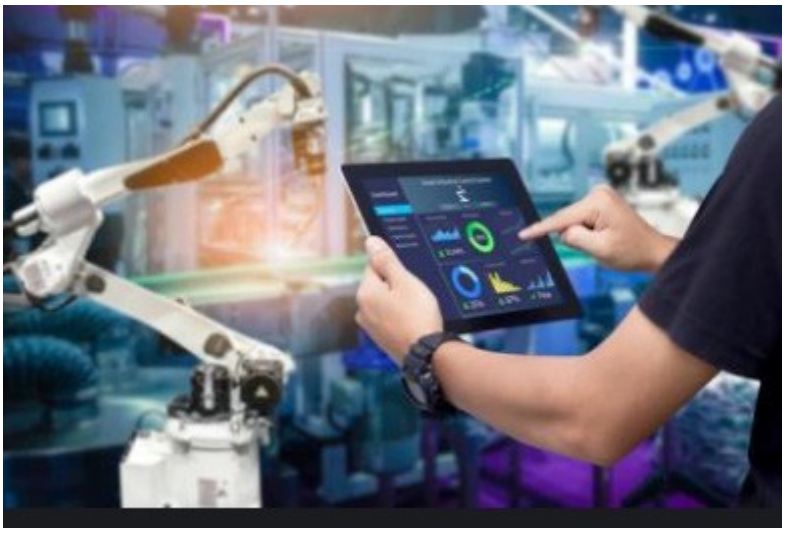
INNOVATION IN THE FOOD INDUSTRIES: IMPACTS OF THE DIGITAL REVOLUTION



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Executive Summary

The appropriation of digital technologies, artificial intelligence and data-driven learning for more effectively designing, manufacturing, controlling and distributing food that meets consumer demands and respects environmental constraints – for the food industries this is a necessity and a great ambition that the public authorities must actively support.

Food has always been a major preoccupation of our societies, as it is essential to human survival in the same way as health, but more prevalent because the act of eating is repeated several times a day and at all ages. Nowadays, consumers have high expectations of food products in terms of health and sensory, nutritional, cultural, environmental and individual requirements.

To meet this demand, the agro-industrial system that has gradually been established and is now dominant, has its advantages (massification, accessibility, price, sanitary quality), but also limitations at various levels (negative environmental impact, unequal nutritional quality, sometimes unbalanced distribution of value).

Like agriculture and distribution, the food industries must therefore evolve to meet new requirements, which impose the implementation of innovative practices. In this context, the digital transition[1] can bring new opportunities.

1 The process of integrating digital technology into all aspects of the business, requiring fundamental changes in technology, culture, operations and value creation.

Food industries in search of a second lease of life

The food system occupies a central place in the French economy because of the millions of jobs it generates, its cumulative turnover (agriculture: 76 billion euros, food industry[2] : 215 billion euros, distribution: 234 billion euros, out-of-home catering: 97 billion euros) and its positive impact on the French trade balance (7.9 billion euros in 2019). A better performing system would allow to make the most of the multiple components of food: biological (health, sanitary safety), social (pleasure, conviviality, ease of purchase and use), societal (sustainability, solidarity, reduction of waste, naturalness, animal welfare) and economic (food prices, farmers' income, companies' profitability). Within this system, the business of the food industries is to transform agricultural raw materials of variable composition into food and drink of constant composition. For some years now, concerns have been expressed about the competitiveness of these industries, which have been marked by an unprecedented erosion of value (5 billion euros in five years) and a decline in France's share of trade within Europe.

The food industries are structured into three groups of activities: primary processing industries which extract and sometimes transform agricultural raw materials into elementary products (flour, semolina, oils, butter, sugar, starch); manufacturers of food ingredients (enzymes, ferments, nutrients, additives); secondary processing industries which stabilise and package slightly processed agricultural products (milk, meat, fruit, vegetables) and manufacture more elaborate foods (biscuits, cheeses, wines, cold meats, ready meals, canned food, frozen food).

The latter are often "assembly" industries that formulate and structure a foodstuff from its various components. Their innovations are essentially incremental in nature. As for disruptive innovations, which are rather few, they are less and less accepted by consumers, who show their attachment to "natural and traditional food".

In this context, the digital transition is of prime strategic importance in helping the French food industry to meet the new demands of society and regain its competitiveness. Its impact concerns all sectors of business activity: food design and manufacture, product traceability throughout the agri-food chain, eco-design of processes, adaptation to consumer-demand and -purchasing practices, and management of the company[3].

2 In France, the food industry is the leading industrial sector in terms of employment and turnover. However, the largest French group, Danone, is only ranked fifteenth among the major international groups in the sector.

3 The issue of corporate management is not addressed in the report.

Produce and exploit massive and reliable data

The issue of access to megadata (*big data*) and the use of digital technologies to exploit them (machine learning, deep learning and artificial intelligence) is especially relevant for the food industry. Companies must manage the change of scale brought about by the digital exploitation of very large amounts of data in order to "decode" the complexity of food systems by integrating the properties of materials (at all scales), manufacturing processes (dynamic approach) and packaging, consumer demands and environmental constraints. The first step is to have access to reliable databases that take into account the maximum number of parameters related to food characteristics. The second is to exploit them.

Numerous databases on the composition of foods, their environmental impacts, life cycles and food microorganisms already exist. In France, we have for example CIQUAL (nutritional composition of foods), AGRIBALYSE® (environmental data), Num-Alim (digital identity of each food). In addition to these "resource" centres, a considerable amount of information is scattered in internal company reports, results from research projects, as well as in documents that are accessible on the web. Information on the sensory characteristics of a foodstuff or the parameters of a manufacturing or packaging process, or the environmental impacts, is particularly complex and costly to collect. This information is nevertheless indispensable.

As far as the use of these data is concerned, a distinction must be made between the "product model" aimed at gaining a better understanding of the characteristics of foodstuffs and the "predictive model", the purpose of which is to facilitate the design and manufacture of products. It is important to emphasise the importance, but also the difficulty, for the company to equip itself with these predictive models.

Using artificial intelligence and data-driven learning technologies in addition to the traditional mathematical approaches to build these models should make it possible to master the complexity of the phenomena and to take into account the biological characteristics of foods. Modellers will not only have to integrate the knowledge of "scientists", but also that of "practitioners" who rely on well-mastered practices without always knowing the explanatory foundations.

Main recommendations

In the French context, promote a closer relationship between AGRIBALYSE®, Num-Alim and Numagri[1] in order to pool database construction and processing capacities, as well as their interoperability.

Build databases and develop digital tools adapted to objectives specific to the food industry: food-design or -manufacturing, sanitary safety along the value chain, product life cycle.

Significant government support will be required to achieve these objectives.

1 An association whose objective is to conceive, animate and organise the conditions of the standardisation of digital data in the agricultural field.

Better consideration of the complexity of foodstuffs when developing them

The quality of a foodstuff integrates biological, cultural, societal and economic components, which are sometimes difficult to reconcile, and must also take into account the structural complexity of foodstuffs (known as the "food matrix") resulting from the interactions between the molecules used in the formulation of a foodstuff that develop during its manufacture. To design a new product or improve existing ones, professionals must solve multifactorial problems involving variables that often interact with each other.

The spectacular evolution of data-acquisition and -processing tools opens the way to solving these equations. However, this objective is still very ambitious.

While acting on nutritional properties is possible but sometimes complicated, taking into account environmental impacts is much more difficult. For example, given the high variability of nutrient and ingredient contents of products such as pizzas or dairy desserts, it is possible to develop models for improving their nutritional properties while maintaining good sensory characteristics. On the other hand, there are many environmental parameters (climate, energy, water quality, biodiversity, etc.), some of which are also beyond the reach of reliable and validated measurements. It can therefore be very difficult to simultaneously optimise the health value, organoleptic quality and environmental balance of a food, while keeping prices under control.

Main recommendations

Increase fundamental knowledge of the relationships between the structural characteristics of foods and their sensory properties and nutrition.

Build robust food-design and -manufacturing databases.

Develop models and tools for simulating biochemical reactions in foods in relation to their properties. Develop tools to assist in the design of foods.

These different areas should be explored in greater depth in the context of a major multidisciplinary research programme on a European scale.

Towards the digitalisation of factories

The challenges of performance and production flexibility within factories, whatever the industrial sector, require the contribution of digital technologies. These are the challenges of the Industry 4.0 concept, which corresponds to a new way of organising production resources.

The food industries are not immune to this "revolution". The automation of processes and its evolution thanks to artificial intelligence and the deployment of biomechanical techniques (robots, cobots and exoskeletons) is one of the tools at their disposal to meet these challenges. They will have to overcome obstacles that are specific to their activities: the biological nature of products, the development of robots that are resistant to the cold and humidity of the workshops, and the imperative of maintaining health standards. In addition, the production units will have to increase their flexibility (format, product, conditioning, ability to supply food to populations with diversified expectations).

In this context, companies should in an optimal manner:

a) develop “intelligent” equipment and Internet of Things technologies;
b) ensure the storage, structuring and mathematical processing of data;
c) acquire the simulation and visualisation tools needed to produce a virtual replica of all or part of the process. This will be done primarily at the level of large companies and gradually at the level of SMEs.

The shortage of suitable sensors remains a barrier to the widespread digitisation of plants. In addition to those sensors that measure conventional parameters such as pressure or temperature, the design of new sensors is necessary to have access to criteria such as redox potential, water activity and the concentration of various molecules.

Robots, cobots and exoskeletons should progressively find a central place in the food industry. Currently, the main applications concern repetitive tasks with little added value. In order to generalise their use, the following improvements are needed: grippers adapted to soft products, increased performance of 2D vision, acquisition of 3D vision, mastery of new cutting tools (ultrasound, water jet, laser marking).

If the industrial and economic context is not very favourable to robotisation (high proportion of SMEs and VSEs, low margins and limited investment capacities, small production runs), the work context (high cadences, repetitive work, difficult working conditions) should however push companies to equip themselves. In the context of the specific constraints of agro-industrial workshops (cold and humid environment, daily cleaning and disinfection, seizing of fragile, soft and deformable materials, limited investments), cobots and exoskeletons should make it possible to reduce the muscular pathologies of operators. From a social point of view, they will be more easily accepted because of their complementarity with the operators, who will have to master their operation.

As for additive manufacturing, it is difficult to envisage its use in high-volume production lines (e.g. biscuit factory). It should be limited to satisfying requests for highly customised food (product shape) and to its use in laboratories during the development of new products.

Main recommendations

Promote partnerships between research on robotics-cobotics, sensors, agri-food technology, as well as equipment manufacturers and the companies that use them.

Promote the use and implementation of digital tools in ISEs/SMEs/VSEs and offer them free diagnostics.

Set up courses on the digitalisation of production tools (training of technicians and engineers).

Consider the social acceptability of more digitalised and automated means of production.

Use blockchain technology for reinforced traceability

A blockchain built by the members of a "consortium" can be likened to a ledger, no part of which - once written - can be changed, but to which new paragraphs can be added and on which anyone can read the history of a product throughout the manufacturing and marketing chain. An important limitation to its proper functioning is the quality of the data entered into it: its implementation is not a guarantee against initial errors or fraud introduced by any of the members. The loss of confidence in a single link in the chain can undermine the credibility of the entire system.

With digital technologies, especially those that use data collected throughout the product life cycle, blockchain technology should therefore find its place in the food system to ensure a comprehensive analysis of the food history with indicators that integrate all stages "from farm to fork". This tool may prove particularly useful to manufacturers who need to know the history of the products they market, for three reasons: to ensure compliance with product specifications, to be able to react very quickly in the event of a health accident, and to satisfy the growing demand for "transparency" expressed by consumers.

The impact of the energy consumption on the environment when using blockchain technology is a criticism often put forward. In the case of the food system, this environmental risk is negligible, as we are dealing with "pseudo blockchains" ("consortium blockchains" with a small number of participants and "private blockchains" within a company).

Another criticism is that blockchain technology is a "black box" that stores information that consumers would like to have access to – but cannot. This access depends on the goodwill of the members of the "consortium". This criticism deserves serious consideration.

Main recommendations

Continue work on national, European and international interoperability between blockchains.

Standardise methods for informing consumers about the many dimensions of food quality, especially nutritional and environmental.

Support SMEs and VSEs wishing to adopt this tool, once the "best practices" of blockchain technology within the food system have been consolidated.

These recommendations could find their place within the national strategy to make France "a blockchain nation" unveiled by the Directorate General for Enterprises at the Paris Blockchain Conference on 15 April 2019.

Better consideration of environmental impacts

The most significant levers of action available to the food industries to produce in a more "sustainable" way are: supplying factories with agricultural products with low environmental impact, reducing energy and water consumption, optimising the upstream and downstream supply chain of factories, and reducing single-use plastic packaging.

Life cycle analyses show that agricultural products make a major contribution to the environmental rating of a foodstuff. Factories must therefore ensure that they source from producers who are committed to reducing the environmental impact of their activities. The company's participation in blockchains should give their factories access to the data they need to make their choices. In order to ensure the traceability of the entire supply chain, interoperability of the blockchains in which the company participates with the blockchains in which the suppliers (of the ingredients that go into the composition of a food) participate independently, must be achieved.

The French food industry is the third largest industrial sector in terms of energy consumption. It is also a major consumer of water. Some of the water used must comply with sanitary standards specific to foodstuffs. Very significant energy and water savings have been achieved in many sectors (starch production, sugar production, dairy, biscuit production). Among the gains expected from the deployment of digital technologies are: optimal use of robots and cobots, instantaneous response to production incidents with better machine control, preventive maintenance and interconnection of the production system giving access to a global view of all the parameters on which the smooth running of the factory depends.

The transport of products within the food chain is another significant component of the impact of food on the environment, and this under two aspects: greenhouse gas emissions and release of fine particles into the atmosphere. Industries can integrate the possibilities offered by the digital revolution in four areas: storage, packaging, transport, and respect for the sanitary quality of products (a specificity of the food supply chain). Good packaging management and the reduction of food waste (not developed in this report) are also essential components of the optimisation of logistic circuits.

Main recommendation

Of all the environmental impacts associated with the life of a foodstuff, climate change is the most worrying because it is universal, almost irreversible (on the scale of many future generations) and its effects on the planet and human societies are potentially dramatic. The effort of food system professionals should focus on this parameter as a priority.

The convenience food industry (e.g. ready-made meals) threatened by robots and virtual catering

With digitalisation, home cooking (food processors, "smart" ovens) and home delivery (virtual catering) could become formidable competitors to the ready-made meals industry.

Already, multifunctional food processors (actually cobots) can prepare a wide range of dishes, both sweet and savoury. In addition to their culinary function, some of them offer "services" designed to help consumers improve their daily diet. The interdisciplinary *Open Food System* programme, a research consortium coordinated by the SEB Group, aims to design new, more "intelligent" cooking appliances that can automatically (without contact or human intervention) modulate cooking parameters to preserve the organoleptic and nutritional qualities of food. Home cooking is also facilitated by the "intelligent" ovens that are beginning to find their way into the kitchens of the wealthy.

Other competitors of the food industry, the "new" catering, are becoming virtual for consumers and are based on the existence of a kitchen that is "invisible" to its customers, if not on the Internet. Everyone can order the dishes offered on dedicated websites and have them delivered where and when they want. It is sometimes possible to customise the dish (gluten-free, lactose-free, mixed salads, etc.). As for the “cook” he also buys from suppliers he often only knows "digitally". The growth of this sector is spectacular.

New services for businesses

Digital technologies enable companies to identify changes in consumer demand more accurately and quickly. SMEs, often more responsive than large companies, are well placed to react quickly to these developments. Public authorities could help them to do so. However, the legitimate concern of companies to better respond to societal demand is gradually shifting towards a more marketing approach that consists of specifically targeting individuals, paying less attention to the collective interests of society. Consumer choices become less free than they might appear. These personalised targeting policies are not without ethical problems that companies must address.

The majority of food industries are small companies whose products are representative of traditional French "know-how". The inadequacy of their resources is an obstacle to accessing international markets, even though they could be ambassadors for French gastronomy. The use of digital technologies should make it possible to reverse this trend by pooling promotional and marketing tools. Two initiatives could be launched: the development of a digital catalogue of products offered for export and the provision of access to shared warehouses capable of delivering orders to their customers anywhere in the world as quickly as possible. These initiatives should be accompanied by a reflection on the adequacy of the gustatory properties of "typically" French products to the demands of foreign consumers while maintaining the very positive image of French local products.

Main recommendations

The impact of monitoring digital purchases in order to "know everything" about a consumer's behaviour and sending him targeted messages raises ethical questions that few manufacturers or distributors seem to have addressed. Researchers and company managers should work together to enlighten society and the public authorities on this subject.

A pooling of resources (shared catalogues and warehouses) would help medium and small companies to better export their products.

Regional professional organisations in liaison with the presidents of the regions could play a driving role in this area.

New services for consumers

As a result of widespread access to websites, social networks and digital applications, consumer purchasing practices are changing rapidly (online ordering, quicker and more complete access to food characteristics, growth in out-of-home consumption, choices that are increasingly influenced by the enterprises in question). The goal of a more personalised diet is becoming more realistic with the possibility of having "tailor-made" meals delivered to the home, replacing the need to buy ingredients and then cook them. For those who wish, it is becoming easier to source local produce. Interestingly, the recent Covid-19 health crisis has served as an accelerator for direct sales and short circuits. Local actors have often created their own websites, an effort that has been amplified in some regions by the creation of free digital platforms listing producers and merchants delivering their products to homes in a given geographical area. The use of digital technology could be further extended to encourage the development of the sector by creating a national platform of the "Doctolib"[4] type, which would give more visibility to these initiatives by not limiting them to insiders.

Another factor in the evolution of food practices is the access to information on the nutritional and environmental value of food. This information is provided on social networks and on digital applications that are "self-validated" by the managers of the start-ups that have put them online. A new generation of applications that take into account the specificities of consumers (allergies, intolerances, special diets, societal and cultural choices) is beginning to emerge. The messages sometimes become unintelligible as they can be contradictory. It is worrying to note that consumers do not give more credence to materials validated by health authorities than to those proposed by independent start-ups.

Main recommendation

Apps that claim to help consumers with their purchases have an effect on consumer behaviour and consequently distributors and food companies looking for good ratings. In view of their success and impact, the public authorities should refer the matter to the Anses[5] in order to assess the relevance of the methodologies used to construct the ratings that these applications attribute to food and drink

4 Doctolib is a Franco-German company founded in 2013 by Stanislas Niox-Château that offers an online consultation management service for healthcare professionals and an online appointment booking service for patients all over France and Germany (Wikipédia).

5 Agence nationale de securite sanitaire (National Health Safety Agency)

Many consumers complain about the opacity of the food industry, which produces food where they do not understand either where it comes from or how it is formulated and manufactured. They are concerned about this and are asking for more transparency.

In addition to the possibilities they offer manufacturers to optimise all their processes, digital technologies can help them to better inform consumers. One of the characteristics of these technologies is that they allow a global systemic approach to the entire agri-food chain. Industrialists therefore possess a wealth of information, much of which should be made available to their "customers".

Furthermore, manufacturers must better explain that they have to rely on scientific and technological advances, particularly those of digital technology, in order to offer French consumers quality food. They will also have to address the ethical issues raised by the collection and use of data on individual consumer behaviour.

An important question is related to the use of digital technologies by agri-food SMEs, which constitute the main industrial fabric for this sector. The main issues concern the acquisition of know-how and technical support for the implementation of these tools.

Solutions to these challenges must be found quickly and under acceptable economic conditions, with the support of public authorities.