Rama (Ruth), Wilkinson (John), « Innovation and disruptive technologies in the Brazilian agro-food sector »

Résumé – Cet article analyse les transformations du système agro-alimentaire brésilien à la lumière du cluster des technologies dites disruptives. La perspective de la chaine agro-alimentaire est adoptée pour mieux comprendre leur impact. Dans ce cadre, nous développons une analyse spécifique de l'industrie agro-alimentaire sur la base d'une enquête officielle de l'innovation, d'une enquête complémentaire de sociétés grandes et moyennes, et d'une analyse de la bibliographie académique et spécialisée.

Mots-clés – IAA, biotechnologie, TIC, digitalisation, technologies disruptives, Brésil

Abstract – This article analyses transformations in the Brazilian agrofood system in the light of a cluster of advanced technologies, which have been designated as disruptive both in the academic literature and in the international policy literature. Within the framework of the agrofood chain perspective we develop a specific analysis of the food industry drawing on an official innovation survey, a complementary survey of medium and large firms, and an analysis of academic and specialist literature.

Keywords – Agro-food sector, biotechnology, ICT, digitalization, disruptive technologies, Brazil

INNOVATION
AND DISRUPTIVE TECHNOLOGIES
IN THE BRAZILIAN AGRO-FOOD SECTOR[1]

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INTRODUCTION

This article analyzes innovation in the Brazilian agro-food chain and, specifically, what has been designated as disruptive technologies both in the academic and international policy literature – TIC, digitalization, big data, artificial intelligence, advanced biotechnology, nanotechnology. Our analysis adopts an agro-food chain perspective to capture the existence or otherwise of different dynamics at each of the major stages of agro-food production, distribution and consumption. In particular, in the Brazilian case, we identify a sharp distinction between the agribusiness sector, which is competitively integrated into global markets and investments, and the packaged food and beverages (F&B)

industry, which although dominated by global players is fundamentally geared to the domestic market. Within this framework the food and beverages sector is subject to a specific investigation based on the analysis of official innovation survey data, a complementary survey of medium and large F&B firms, together with a review of academic and specialist literature. The Brazilian case is analyzed within the global framework of technological change in agro-food where the diffusion of the above clusters of technologies is shown to be affecting business models, competition and consumption patterns not only in the global North but also in an emerging economy, such as Brazil.

From the point of view of a firm, a potentially disruptive technology is understood to be a technology outside its core area of expertise making possible new products and processes valued by the consumer (Birkinshaw et al., 2018). Discontinuous technological change can cause an upheaval in dominant firms, in the existing market structure, and in industries. Therefore, disruptiveness needs to be evaluated relative to the existing business model. Previous studies (Aschhoff et al., 2010; Schuelke-Leech, 2018) designate digitalization, advanced biotechnology, nanotechnology, the Internet of Things (IoT) and Information and Communication Technology (ICT) as disruptive technologies. We focus on those most frequently adopted in the food chain, i.e., advanced biotechnologies, digitalization and ICT.

As shown by bibliometric analysis and reviews of the literature, comprehensive studies on disruptive technologies in the food chain are scarce (Li et al., 2018; Christensen et al., 2018). Moreover, they rarely draw attention to emerging economies. This article contributes to filling this gap. The research is mainly of an exploratory nature, but provides new elements towards an understanding of disruptive technologies in the food-chain.

In the following sections, previous studies are reviewed and national statistics analyzed, in addition to information provided by web pages, the business press and interviews with key actors in Brazil. The statistical data for the F&B industry are taken from the 2014 edition of PINTEC[2], a national innovation survey which follows methodologically

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2   https://www.ibge.gov.br/estatisticas-novoportal/multidominio/ciencia-tecnologia-e-inovacao/9141-pesquisa-de-inovacao.html?=&t=o-que-e December 2018 (this is the last available PINTEC edition).

the Community Innovation Survey (CIS) of the European Union (EU) and the criteria of the Oslo Manual which facilitates international comparisons. PINTEC is carried out every three years by the IBGE (Brazilian Institute of Geography and Statistics) and collect information on enterprises active in the industry, electricity, gas and selected services. Interviews are generally conducted by telephone. The PINTEC data are available on line but, to our knowledge, recent data for the F&B industry have until now not been analyzed. In some cases, we worked with Tables especially prepared on request, which provide interesting intra-industry insights; these data are not available on-line. Direct access to the data, which would enable the researcher to perform econometric analyses on innovation similar to those performed on CIS-data, remains quite restrictive. In addition, 117 F&B firms with more than 100 employees, of which 49% very large enterprises with more than 500 employees, were interviewed to gather information on technology adoption not provided by PINTEC. This survey was performed through the Internet from June to November 2017[3]. In addition, a small selection of leading firms identified in the specialist literature was identified via Skype and e-mail.

We first present a literature review and the principal research questions. This is followed by a discussion of the features which are specific to the Brazilian agro-food system viewed as a whole. The next section analyzes the Brazilian Food and Beverage sector (F&B) and innovation trends in the light of new consumer tendencies and new patterns of regulation. In the final section, we analyze the IBGE PINTEC data which is complemented by the results of a survey carried out in the framework of the *Industry 2027* research project mentioned above in which the authors participated, together with related research results, focusing especially on advanced biotechnologies and ICT. The conclusions emphasize the importance of combining survey analysis and literature reviews with data from the specialist Journals and sites which are able to capture the significance of new patterns of innovation not readily identifiable in the survey data.

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3   For details, see Annex Pesquisa de Campo do Projeto Indústria 2017 *in* Wilkinson & Rama, 2018, p. 103.

1. LITERATURE REVIEW AND RESEARCH QUESTIONS

The F&B industry includes both primary and secondary processing of agricultural products. Innovation refers to new products and new industrial processes; new types of packaging; new labeling information; new formulas (flavors, additives, etc.); increased variety of products; new marketing methods, and new logistical methods (European Commission, 2016). Different manufacturing sectors display different patterns of innovation, and the literature highlights the specificities of innovation in the F&B industry, such as the importance of incremental innovation. This has been associated with a traditional view of consumers as conservative and likely to reject radical innovations. Today, however, changing patterns of food consumption are driving radical innovation often in directions unanticipated by the food industry – organic, vegetarian, vegan and more generally fresh rather than highly processed products (Batte et al., 2007).

At first sight, a contradiction between the rising demand for fresh food and the rising demand for more processed food is apparent. A study in 79 countries reveals that ultra-processed foods dominate food supplies of high-income countries and their consumption is rapidly rising in middle-income countries, such as Brazil (Monteiro et al., 2013). However, the consumption growth of ultra-processed foods is inversely related to the country's GDP per capita. According to the above-mentioned study, the predicted growth for very high-income countries is close to zero. Many other studies show a rise of the demand for fresh food and even for organics in these countries, and in high-income segments of emerging markets. It should also be recognized that highly processed foods may be associated with healthy and organic foods as in the rapidly expanding category of energy bars. Convenience and time pressures also mean that eating practices combine fresh and processed foods.

Schumpeter argued that large companies active in monopolistic markets are more prone to innovate than smaller enterprises since they have at their disposal larger financial resources for R&D. F&B is a very Schumpeterian industrial sector not so much because high R&D expenditures are necessary to innovate in F&B but rather that

innovators need substantial complementary assets to advertise and market new foodstuffs. This view is confirmed by a number of empirical studies while others show that the contribution of very large firms to F&B innovation varies by country and sub-sector. The F&B industry has often been characterized as a "traditional" industry since its R&D/sales ratio is lower than that of other industries, such as the electronics industries. However, as early as the 1990s, research work detected that this industry was already an important *user* of innovations produced by upstream industries, such as biotechnology, and Information and Communication Technology (ICT). Consequently, cooperation with external partners for innovation seems to be increasingly important in this industry. A case study on British F&B firms suggests that cooperation with high tech sectors is especially fruitful (Trott & Simms, 2017).

There is a scholarly debate on the exact meaning of "disruptive technologies" (Schuelke-Leech, 2018). Most authors consider that disruptive innovations are radical, breakthrough innovations, as opposed to incremental or evolutionary innovations. These innovations are at the core of the different technological dynamics displayed by different types of industries. In most industries, the populations of innovators change rapidly and the technological landscape is turbulent (Cefis & Orsenigo, 2001). These industries are dominated by vibrant communities of new entrants searching for new solutions and opportunities. Disruptive technologies are rarely employed, at least initially, in established markets but tend, instead, to be valued in emerging markets or at the bottom end of the market since such technologies often contribute to the introduction of cheaper products (Christensen et al., 2018). In contrast, the F&B industry has been characterized by incremental innovation and long cycles of technological change controlled by incumbent firms that mainly cater to mainstream consumers (Alfranca et al., 2004). However, these analyses do not take into account the perceptions about new products by previously excluded segments of the population, national or international.

In the light of the above, the research examined the degree to which disruptive technologies are becoming diffused in the Brazilian food chain and where in the food chains such changes are taking place. It also investigated the motives for the adoption of these technologies and the main agents of disruption. Examples taken from the global North are drawn in to place the Brazilian case in perspective.

2. THE SPECIFIC FEATURES OF BRAZIL′S AGRO-FOOD PROFILE

Although global players dominate all its different segments, Brazil′s agro-food sector exhibits specific features which are important to take into account when evaluating the dynamic and impacts of potentially disruptive technologies. From being a net importer of food fifty years ago, Brazil has become one of the world's leading agricultural exporters. This evolution was to a large extent the result of extensive intervention by the State to open up new areas to agriculture and to promote innovations that made poor tropical soils suitable for producing temperate climate crops (Hopewell, 2016). In spite of its high logistical costs Brazil is now globally competitive and leader in the production and export of a wide range of agricultural commodities. It leads in sugar, coffee, orange juice and beef and is in second place in the case of soy and poultry and fourth in pigs. Two decades ago its principal markets were in Europe which stimulated the adoption of quality criteria and value-added strategies. Today the Asian and particularly the Chinese market is the overwhelmingly dominant destiny and demands only basic unprocessed commodities, and grains in the case of soy (Wilkinson et al., 2016).

Such a scenario favors innovation in the agricultural segment of the Brazilian agro-food chain where we are witnessing a rapid uptake of digital technologies which promise lower costs and higher productivity and greater efficiency in the management of large farming areas. In this light, the emergence of mega farms on the Brazilian grain frontier cannot be exclusively analyzed in terms of financialization and speculation but must take into account the dramatic scale effects of digital farming (Padua, 2017). Digital solutions are also crucial in confronting the formidable logistical problems posed by the advance of Brazil′s agricultural frontier into the center and north of the country and all the global traders are currently incorporating digital SAP (Systems, Applications and Products, that is the name of the German company, world leader in digital data management software) and blockchain systems. Vieira Filho and Fornazier (2016) observe that Brazilian agriculture is highly capital intensive, much more so than other sectors of the Brazilian economy. In this respect, they argue, Brazilian agriculture is unique relative to other emerging

economies. Their econometric model suggests that in Brazil agriculture may be competing with manufacturing for capital and qualified labor.

The new innovation model based on venture capital and hubs of start-ups is very much present in Brazil and is concentrated again on agricultural innovations, particularly in the form of software applications for digital control over the use of agricultural inputs. Here also the entry of new global players is evident, such as IBM and its super computer, Watson, in a joint venture with the Brazilian firm Agrotools for the production of digital farming applications using big data and machine learning[4]. According to reports in the specialized business literature, the application of advanced digital and genetic research for the production and processing of raw material is well advanced in the grains and the biomass (sugar cane and cellulose) sectors involving leading Brazilian firms in each of these sectors – Algar and Caramuru in grains, Raizen in sugar cane and Fibria in cellulose.

Nevertheless, a challenge for innovative responses is the traditional separation between a largely uncompetitive food and beverage industry basically geared to the domestic market and the extremely competitive agribusiness commodity sector. Regulatory and consumer pressure in Brazil for the development of new ingredients to replace sugar, salt and fats, provides an important stimulus for greater cooperation between the grains and the food sectors[5]. Globally, similar pressure is leading F&B firms to research new molecules, using big data and machine learning, with a view to eliminating the above "bads" with no loss of traditional tastes and textures.

3. THE BRAZILIAN F&B INDUSTRY IN THE LIGHT OF NEW CONSUMERS AND REGULATORY DYNAMICS

Although also dominated by the global leaders, the Brazilian F&B sector is fundamentally oriented to the domestic market, where the

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4   https://link.estadao.com.br/noticias/inovacao,start-ups-brasileiras-apostam-no-potencial-do-agronegocio-para-crescer,10000089431.

5   http://dab.saude.gov.br/portaldab/ape_promocao_da_saude.php?conteudo=reducao. December 2018.

dynamism of demand has been constrained by Brazil´s regressive income distribution. Global leaders such as Nestlé have been part of Brazil´s food industry since its consolidation in the first decades of the 20th century, but the liberalization of the economy and the control of inflation achieved in the 90s led to a new entry of foreign firms. Levels of concentration in the different industry segments are higher than in Europe and even the United States, and firms with more than 500 workers are responsible for 70% of production (European Commission, 2016). According to PINTEC, they were also responsible for 79% of internal R&D in 2014.

Although export competitiveness is not the principal driver in the case of the Brazilian F&B sector, this latter is affected by the same pressures from both changing food practices/consumer demand and regulation which are transforming global markets. The Brazilian diet has undergone important changes. According to UNIDO there has been a clear increase in the demand of meats, fish, fruits and vegetable in the period from 2000 to 2009 and stagnation in the demand of grains[6]. The degree of food and beverage processing has also increased according to a study of 11 metropolitan areas between 1987 and 2003 conducted by Monteiro et al. (2010). These apparently contradictory tendencies can be better understood in the light of the need to negotiate conflicting pressures affecting eating practices – time and convenience versus health and "freshness", with both being strongly affected by price considerations. In addition, highly processed foods now constitute a component of "healthy" foods – snack bars, products with less or no sugar/salt/saturated oils. These are often based on the disruptive technologies under study and have given rise to a new generation of food firms contesting the leading incumbents, but also being acquired by them[7].

Food is at the center of consumer concerns with personal and collective well-being and the combatting of diet related illnesses becoming a central public policy health goal. The Health Ministry calculates that more than half the Brazilian population is overweight and that some 20% are obese. In Brazil, as in other countries, dietary guidelines favor fresh products and the Ministry of Health has singled out "highly processed food products", products with more than four ingredients, which is the central feature of

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6   www.unido.org
7   Pacete, L. G. "Quem são e o que fazem os start-ups apoiados pela Nestlé", www.meioe-mensagem.br, 17/01/2019.

the food industry, as food to be avoided. Agreements have been reached between the Government and Brazilian representatives of the food industry to substantially lower the sugar and sodium content of food products. Globally a central goal of the food industry, similarly pressured by Government guidelines and regulation, is to decrease or eliminate sugar, salts and saturated oils while maintaining food´s traditional tastes, smells and textures. The search for new ingredients is bringing together the global commodity traders, food industry leaders and firms/laboratories which specialize in the identification of new molecules using big data analytics, synthetic biology and CRISPR/Cas9 gene editing techniques[8]. The global players who are also food industry leaders in Brazil are in the forefront of these initiatives. These trends provide a favorable climate for the development of new products – energy snack bars, new "substitute" products without the traditional ingredients – creating opportunities for the emergence of new firms and new retail outlets. All the leading food firms – Nestlé, ABInBev, Brazil Foods (BRF), Mondalez, Ingredion and Duas Rodas – have R&D facilities in Brazil and are involved in the application of front line digital technologies – the IoT, artificial intelligence and big data analytics[9]. Their lines of research are convergent with global trends – reduction/elimination of sugars, salts and trans fats – without loss of taste and texture.

The importance of new consumer trends acting as disruptive forces in the food industry is most clearly evident in the United States where the incumbent food leaders and their brands, often called heritage firms, are now under attack from a new generation of alternative food firms which have gained national access to supermarket shelves. Such firms have often benefitted from a new model of innovation based on the venture capital financing of start-ups, many of which are now emerging from Silicon Valley. The most radical of these firms are targeting substitutes for meat and animal products which parallel the huge upturn in vegetarian/vegan/flexitarian food consumption practices[10]. In response, the "heritage" firms reposition themselves as the "fresh packaged" food industry, buy-up the new food start-ups while maintaining their separate identity, or shift from mainline food to specialized concerns with advanced technological health products.

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8   ETC Group, 2008, *Commodifying Nature´s Last Straw?* October. www.etcgroup.org
9   Valor. 2017. Inovação Brasil. As 150 Empresas mais Inovadoras. Julho, www.valor.com.br
10   CBinisghts. 2016. Food Replacement Market Map. 39 Start-ups offering alternatives to meat, dairy, gluten & more. https://cbinsights.com

Similar food consumption trends are now being identified in Brazil and a new generation of food company start-ups on the US model are beginning to make themselves felt, especially in the snacks and food delivery sectors[11]. Nestlé and Ambev, in collaboration with the Santander Bank, are now housing nineteen food start-ups at Nestlé´s headquarters in São Paulo with a view to accelerating the development of their products[12].

Major disruptions facing the traditional food industry in Brazil are associated with the way new digital technologies are accelerating trans-formations in the food-service sector, especially home delivery of meals in various forms. Initially based on start-ups using smart-phone aps, GPS technology and big data analytics, this sector is going through a process of rapid concentration and integration into global food services companies. On the other hand, direct on-line sales provide a radically new opportunity for food firms to loosen the grip of large-scale retail, especially for specialized storable products of which Nestlé´s line of infant foods is a notable example. The retail leaders are similarly implementing the SAP digital management systems to explore the interface between on and off-line sales, are participating in social networks to anticipate demand, initiating automatic payment systems via smart-phones and together negotiating the standardization of mobile commerce, "m-commerce".

4. THE IBGE PINTEC SURVEY DATA AND ASSOCIATED RESEARCH, FOCUSED ON BIOTECHNOLOGY AND ICT

As indicated above, the specialist and journalistic literature provide important examples of innovative firms in F&B which are beginning to reproduce in Brazil patterns also identified in the global North. These, however, are still difficult to perceive in a general survey of innovative activity in the F&B industry, although some of its data are consistent with this characterization. According to the PINTEC 2014 Survey,

11   Food Engineering Magazine. 2015. The World´s Top 100 Food & Beverage Companies
     – 2015: Change is the New Normal. 09/09. www.foodenginieringmag.com
12   See note 6.

innovative firms amount to 45% of F&B companies as against 40%-43% during 2000-2005 (de Carvalho & Furtado, 2013) confirming a consolidation and slight increase in the percentage of innovative firms. PINTEC 2014 defines as innovative those companies that launched new products onto the market, implemented new industrial processes or either have had ongoing or abandoned innovative activities during 2012-2014. However, most Brazilian F&B firms are engaged exclusively in imitative innovation, which may be innovative for the firm but is already present in the Brazilian market, or innovative in Brazil but already present in global markets.

The role of auxiliary industries and services as inducers of new technology diffusion is substantial. Around 74% of the F&B firms turn to other firms, probably those active in auxiliary industries, or to institutions for implementing new industrial processes. It was found that in terms of embodied knowledge measured by R&D expenditures, the Brazilian F&B industry mainly benefits from flows coming from knowledge-intensive business services (Gonçalves et al., 2017). According to PINTEC 2014 data, 67% of Brazilian F&B firms engaged in cooperation for innovation prefer partnerships with suppliers. The European CIS data show that, in the EU, the preferences of F&B firms are quite similar. Small companies in the Brazilian F&B industry give particular value to collaborations with universities (Wilkinson & Rama, 2018). This feature is also characteristic of SMEs active in the EU food and drinks industry, especially those located in rural areas (Minarelli et al., 2015). These findings corroborate the idea that an understanding of innovation in the food industry requires attention to the broader innovation ecosystem within which it operates and confirms the importance of combining survey data with the detailed, often case-study analysis, to be found in the specialist literature.

In the specific field of biotech, however, cooperation of Brazilian agro-food companies with institutions seems to be weak, in spite of the numerous biotech patents of EMPRAPA, the most important Brazilian public research center for agro-food technology, and the outstanding role of universities, which perform 80% of Brazilian biotech research (Gutman & Lavarello, 2012). This contrasts sharply with patterns of cooperation among biotech firms in industrialized countries, especially during early stages of diffusion (Holl & Rama, 2012).

In Brazil, as in other competitive food producers, such as The Netherlands or Spain, diffusion of biotech in the economy is led by the agro-food sector, rather than by the pharmaceutical industry (Senker & Mangematin, 2008). In the literature, diffusion is usually measured by the number of companies that have adopted the new technology.

According to PINTEC 2014, F&B companies account for 67% of companies active in the Brazilian bioeconomy. Around 13% of Brazilian F&B firms were involved in biotechnology in 2012-2014, a percentage similar to that observed in Spain (Holl & Rama, 2012). Firms engaged in biotech are the most innovative of the Brazilian F&B industry (Table 1). In the food industry, differences in the share of innovative firms are noticeable in all strata, even in those of firms with 10-29 employees. In the beverages industry, differences are apparently greater in the case of SMEs.

TAB. 1 – Share of innovative firms in the Brazilian food and beverage industry, by employment strata. All firms and firms engaged in biotech (%).

	All F&B firms	F&B firms engaged in biotech
Food manufacturing		
Total	45%	58%
-10-29	43%	62%
-30-49	45%	61%
-50-99	44%	51%
-100-249	49%	64%
-250-499	56%	72%
≥ 500	62%	66%
Beverages		
Total	43%	86%
≥ 500 [1]	74%	89%

Source: Authors' elaboration based on PINTEC 2014.

There is a noticeable presence of SMEs: 77% of the Brazilian F&B firms engaged in biotech have fewer than 50 employees. Advanced functions such as R&D are substantial in all the size strata, even in companies with 10-29 employees (Wilkinson & Rama, 2018). This characteristic needs

to be stressed since, the transition from the *adoption* of biotechnology to the *production* of biotechnology is far from automatic. The evidence confirms the results of previous studies that point to "young" suppliers of flavors and ingredients of the Brazilian F&B industry being R&D intensive, in spite of their small size (Kannebley Junior et al., 2009). Although the F&B industry is mainly a Schumpeterian industry, this is clearly one of the sub-sectors of the Brazilian F&B industry in which SMEs can make a contribution to innovation, and the diffusion of this technology is introducing important changes in the structure of this industry. These findings are convergent with the rise of new *agfood* start-ups identified in the specialist literature.

As shown by the literature on consumption, public acceptance of innovation in the food chain is shaped by perceptions of both risks and benefits. Compared to the ambivalence with regard to biotech, ICT is a technology well accepted by food consumers. An important reason is that its adoption at the company level goes hand in hand with benefits for consumers, such as improved quality controls and the traceability of food (Galliano & Orozco, 2013). The adoption of ICT facilitates greater coordination between different segments of the food chain, control of logistic costs, and the differentiation of foodstuffs. It also facilitates exports and, within the same country, intra-company interactions between establishments located in rural areas and establishments located in urban areas. Brazilian policies have not especially promoted the adoption of ICT by the food chain or the traceability of food. The adoption of measures of traceability in the meats sector has occurred under pressure from importer regions such as the European Union. The adoption of traceability in soy and meat has also been a response to pressure from civil society organizations in connection with deforestation in the Amazon region. Brazilian retail is also demanding more traceability as a response to varied consumer concerns. A new impulse to the adoption of IT comes from the rise of hubs of agri start-ups focusing particularly on IT software.

ICT is disruptive in that its diffusion is introducing changes in the structure of food markets. There is competition between countries for leadership in the setting of standards for the IoT and this process is likely to affect the respective competitiveness of these countries in international food markets. Competition also takes place at another level.

The traceability of foodstuffs is considered one of the cornerstones of EU competitiveness, and exporter countries that cannot fully adopt this practice are likely to be excluded from the most affluent food markets. The disruptive effects of ICT diffusion can also be noticed in national food markets. In Brazil and elsewhere, small processors who cannot comply with quality or safety levels established by retailers tend to be left out (Belik & Rocha dos Santos, 2002). In the EU, supermarkets are legally responsible for the compliance with EU regulation and this circumstance has stimulated the vertical integration of the food chain and a significant involvement of retailing in self-regulation (European Commission, 2016). This approach has been consistently followed by their subsidiaries located in Brazil and in other developing countries, and by their domestic competitors (Reardon & Farina, 2001). The early adoption of updated ICT by supermarkets in Brazil reflects this process.

ICT used by the food chain is mainly produced by upstream industries, although very large F&B processors also have been patenting in this field since the 1990s. Certain large F&B firms, such as Barilla, are cooperating with suppliers of technology to implement the IoT and, consequently, improve the traceability of their products. Also, retailers such as Walmart and Target have created their own information systems and require that these systems be adopted by their F&B processors. Supported by the Chinese Academy of Science and by the US National Science Foundation, a review of research into industrial applications of IoT notes that, worldwide, retailers are one of the largest adopters.

In industrialized countries, the diffusion of ICT in the food chain seems to be substantial (Galliano & Orozco, 2013). Unfortunately, PINTEC does not provide information on diffusion in the Brazilian F&B industry. Therefore, we explored an approximation provided by the same source. F&B companies were asked to indicate whether the acquisition of software was useful to launch new foodstuffs into the market or implement new industrial process. The definition of software is comprehensive since it includes design, engineering, processing, data transmission and automation. Around 22% of F&B firms consider that such acquisitions were medium or highly important. This percentage rises to 25% of firms in the 30-49 employee bracket, which suggests that SMEs are playing a role in software diffusion.

To obtain further information on ICT diffusion in F&B manufacturing, an "ad hoc" survey covering a sample of domestic firms with more than 100 employees was carried out as indicated in the Introduction. Although we do not claim that the survey is statistically representative of the entire F&B industry, it gives some interesting information on the diffusion of computer technology (Industry 3.0) and integrated digital technology systems (Industry 4.0) in this stratum – information which is not provided by PINTEC. Digitalization includes the vertical networking of intelligent manufacturing systems, the coordination of manufacturing and logistics, and the integration along the entire supply chain. The results are presented on Table 2. Column 1 shows the % of adoption for all entrepreneurial functions, and columns 2 and 3 for two specific functions. The percentage of adopters of computational and digital technologies clearly increases when dealing with technologies used for coordination with suppliers. Also, *expectations* of respondents (data not displayed) concerning the future implementation of digitalization mainly concerned the facilitation of relationships with suppliers. This would suggest that a powerful reason for adoption may be to facilitate food traceability. Digital technology also seems to be relatively more employed for product development. Interestingly, Brazilian manufacturing firms as a whole with more than 100 employees were less prone to adopt full scale digitalization than F&B firms of similar size (1.6% versus 1.9% of companies). In the US, in contrast, F&B companies have been slower to adopt digitalization when compared to other manufacturers[13].

The available information seems to predict a quicker pace of Industry 4.0 adoption in the F&B industry than in all Brazilian manufacturing industries, at least concerning investment in fixed capital (Table 3). The largest differences concern those investments in the specific area of relationships with suppliers: 42% of the surveyed F&B firms declare to be engaged in such projects *versus* only 37% of the manufacturing companies. Furthermore, F&B firms also surpass manufacturing firms concerning fixed capital investments designed, specifically, to facilitate the relationships with clients (37% of F&B firms versus 33% of manufacturing companies). The data suggest that, in implementing digitalization, the F&B companies are mainly striving towards closer

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13   https://www.forbes.com/sites/michaelmandel1/2018/11/29/why-digitizing-food-manufacturing-can-boost-living-standards/#474acf026308 April 2019.

relationships with the rest of the food chain. The respective shares of firms with ongoing Industry 4.0 projects in the area of training is quite similar. In contrast, F&B firms are less likely to be engaged in R&D-related 4.0 projects. An exception is the case of 4.0 ongoing R&D projects concerning specifically the design of new products where F&B firms outperform manufacturing firms.

TAB. 2 – Brazilian Food and Beverages Industry
Adoption of computer technology and digital technology, by function
(% of firms).

Technology	All functions (1)	Relationships with suppliers (2)	Product development (3)
3.0 and 4.0 - Of which 4.0	18.3% 1.9%	31% 1%	16.2% 4.3%

Source: Annex Pesquisa de Campo do Projeto Indústria 2017 *in* Wilkinson & Rama, 2018, p. 103.

TAB. 3 – Firms with Ongoing Projects in Industry 4.0
All Manufacturing Industries and Food and Beverages Industry
(% of firms)

Type of project	All manufacturing	F&B industry
Fixed capital investment	34%	37%
Training	33%	32%
R&D	33%	31%

Source: Annex Pesquisa de Campo do Projeto Indústria 2017 *in* Wilkinson & Rama, 2018, p. 103.

CONCLUSIONS

The research presented on this article examined the *degree* to which disruptive technologies have been adopted in the Brazilian food chain and *where* in the food chain the main changes are occurring. We found that the degree of adoption of these technologies is uneven. Disruption does not take place at the same place across the food value chain, with

diffusion being rapid in agriculture and retailing, and less so in the food and drinks processing industry. We also investigated *the motives* for the adoption of these technologies. In agriculture, a major motivation for adoption has been the possibility that they provided for managing very large areas in the agriculture frontier and serve new markets at home and abroad at competitive prices. Retailers have been mainly interested in ICT to obtain information and control over the value chain. They value, as well as food and drinks manufacturers do, the fact that ICT facilitates the traceability of products, which is a feature increasingly demanded by consumers. We also identified the *main agents of disruption* and found that they are heterogeneous: in agriculture, disruptors have been new entrants, incumbents, *"cross-boundary disruptors"* coming from high-tech industries, and start-ups. The large multinational retailers and their native counterparts have played a major role the in diffusion of ICT across the food chain. In the food and drinks industry, disruptive innovations have been introduced by a variety of agents: foreign multinationals, collaborations between food and drinks firms and their suppliers of high-tech, and innovative small and medium-sized-enterprises, especially those active in biotechnology.

At the same time, the leading food firms in Brazil, all subsidiaries of global players, are under pressure to respond to new food demands for fresh, healthy products which are understood to involve a drastic reduction in traditional ingredients – sugar, salt, and fats. For this they are now adopting what has become a global strategy to harness advanced technologies (machine learning and Big Data analytics) to the search for new ingredients which will reproduce traditional flavours, taste and textures without the perceived threats to health associated with the traditional ingredients. As is the case globally, the Brazilian food industry is now facing a challenge from new start-ups identified with health foods, particularly in the snacks and food service sector. These developments are challenging the incumbent leaders who are now developing strategies to control the evolution of these start-ups, but whose success is not guaranteed.

The food industry also has to face challenges posed by both retail and food services which are embracing on-line sales, social network communication and interfacing with smart-phone applications. For some of the food leaders, on-line sales represent an opportunity to at

least partially free themselves from the disciplines posed by large-scale retail. For the F&B sector as a whole, however, while incorporation of IT has become a necessity it does not of itself resolve the central challenge which is posed by new consumer practices increasingly favouring fresh, non-processed foodstuffs.

The use of the new technologies has encouraged a substitution of capital by labour, although the "labour push" out of agriculture has been smaller than in other emerging economies (Spolador & Roe, 2013). Nevertheless, rural migration remains a concern and income inequality is pronounced (Vieira Filho & Fornazier, 2016). The above-mentioned authors calculate that a group of 3.2 million farms exist in extreme poverty and is *excluded from all sectors of economic activity*" (p. 217). At the same time, better remunerated jobs are now available in the new high-tech agriculture, and in logistics or services upstream and downstream the food chain but these new jobs require new capabilities, which are often lacking in rural areas. This points to the need for a substantial public effort in terms of training. Another field requiring urgent attention is related to the technologies that facilitate the traceability of food. As stated, this is an increasing demand of consumers worldwide and the prestige of an export country is nowadays highly vulnerable in case of foodborne disease. More generally, the new innovation model – bringing together venture capital, ag start-ups and innovation hubs – poses a radical challenge to the national agricultural research system which has been so decisive in earlier phases of agricultural modernization.

REFERENCES

Alfranca O., Rama R., von Tunzelmann N., 2004, "Innovation spells in the multinational agrifood sector", *Technovation, 24*, 599-614.

Aschhoff B., Crass D., Cremers K., Grimpe C., Rammer C., Brandes F. et al., 2010, *European competitiveness in key enabling technologies*, ZEW Manheim, Germany.

Batte M., Hooker N., Haab T., Beaverson J., 2007, "Putting their money where their mouths are: Consumer willingness to pay for multi-ingredient, processed organic food products", *Food Policy, 32*(2), 145-159.

Belik W., Rocha dos Santos R., 2002, "Regional market strategies of supermarkets and food processors in extended MERCOSUR", *Development Policy Review, 20*(4), 515-528.

Birkinshaw J., Visnjic I., Best S., 2018, "Responding to a Potentially Disruptive Technology: How Big Pharma Embraced Biotechnology", *California Management Review*, 0008125618778852.

Cefis E., Orsenigo L., 2001, "The persistence of innovative activities. A cross-countries and cross-sectors comparative analysis", *Research Policy, 30*, 1139-1158.

Christensen C. M., McDonald R., Altman E. J., Palmer J. E., 2018, "Disruptive Innovation: An Intellectual History and Directions for Future Research", *Journal of Management Studies, 55*(7), 1043-1078.

de Carvalho S. A. D., Furtado A. T., 2013, "Estratégias Tecnológicas e Dinâmica de Inovação das Empresas Agroindustriais no Brasil", *Revista Gestão & Conexões, 2*(1), 47-75.

European Commission, 2016, *The competitive position of the European food and drink industry*, Brussels.

Galliano D., Orozco L., 2013, "New Technologies and Firm Organization: The Case of Electronic Traceability Systems in French Agribusiness", *Industry and Innovation, 20*(1), 22-47.

Gonçalves E., Perobelli F. S., de Araújo I. F., 2017, "Estimating intersectoral technology spillovers for Brazil", *The Journal of Technology Transfer, 42*(6), 1377-1406.

Gutman G. E., Lavarello P., 2007, "Biotecnología y desarrollo. Avances de la agrobiotecnología en Argentina y Brasil", *Economía teoría y práctica* (27).

Holl A., Rama R., 2012, "Technology sourcing: Are biotechnology firms different? An exploratory study of the Spanish case", *Science and Public Policy, 39*(3), 304-317.

Hopewell K., 2016, "The accidental agro-power: constructing comparative advantage in Brazil", *New Political Economy*, 1-19.

Kannebley Junior S., Porto G. S., Pazello E. T., 2009, "Inovação na indústria brasileira: uma análise exploratória a partir da PINTEC", *Revista Brasileira de Inovação, 3*(1 jan/jun), 87-128.

Li M., Porter A. L., Suominen A., 2018, "Insights into relationships between disruptive technology/innovation and emerging technology: A bibliometric perspective", *Technological Forecasting and Social Change, 129*, 285-296.

Minarelli F., Raggi M., Viaggi D., 2015, "Innovation in European food SMEs: determinants and links between types", *Bio-based and Applied Economics, 4*(1), 33-53.

Monteiro C. A., Levy R. B., Claro R. M., de Castro I. R. R., Cannon G., 2010, "Increasing consumption of ultra-processed foods and likely impact on human health: evidence from Brazil", *Public Health Nutrition, 14*(1), 5-13.

Monteiro C. A., Moubarac J. C., Cannon G., Ng S. W., Popkin B., 2013, "Ultra-processed products are becoming dominant in the global food system", *Obesity reviews, 14*(S2), 21-28.

Padua L., 2017, "Tecnologias digitais vão transformar o agronegocio", *Exame, 10/2017*

Reardon T., Farina E., 2001, "The rise of private food quality and safety standards: illustrations from Brazil", *The International Food and Agribusiness Management Review, 4*(4), 413-421.

Schuelke-Leech B. A., 2018, "A model for understanding the orders of magnitude of disruptive technologies", *Technological Forecasting and Social Change, 129, 261-274.*

Senker J., Mangematin V., 2008, "Biotech innovation in Europe's food and drink processing industry: promise, barriers and exploitation", *in* Rama R. (ed.), *Handbook of innovation in the food and drink industry*, New York, London and Oxford: Haworth Press Inc. Taylor & Francis Group.

Spolador H. F., Roe T. L., 2013, "The Role of Agriculture on the Recent Brazilian Economic Growth: How Agriculture Competes for Resources", *The Developing Economies, 51*(4), 333-359.

Trott P., Simms C., 2017, "An examination of product innovation in low-and medium-technology industries: Cases from the UK packaged food sector", *Research Policy, 46*(3), 605-623.

Vieira Filho J. E. R., Fornazier A., 2016, "Agricultural productivity: closing the gap between Brazil and the United States", *CEPAL Review*, 118, April, 203-220.

Wilkinson J., Rama R., 2018, *Sistema produtivo agroindústria e foco setorial em alimentos processados*, Brasilia (Brasil): Confederação Nacional de Indústria.

Wilkinson J., Wesz Jnr., Lopane A., 2016, "Brazil and China: the agribusiness connection", *Third World Thematics*, 1, 726-745.