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Technological dynamics of the Brazilian food and beverage industry (2000-2011)

Dinâmica tecnológica da Indústria Brasileira de Alimentos e Bebidas (2000-2011)

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Abstract: The Brazilian food and beverage industry is of great social and economic importance to the nation, and technology represents a key factor for competitiveness in the sector. Learning about the past and recent technological dynamics of this industry enables the identification of trends and perspectives that enhance its competitiveness. Based on indicators from the Industrial Survey of Technological Innovation (*Pesquisa Industrial de Inovação Tecnológica* - PINTEC), the present paper discusses the technological and innovative dynamics of the Brazilian food and beverage sector between 2000 and 2011. In general, new technology within the sector has been incorporated rather than created. Enterprise investment in R&D is still low and the sector's technology strategy is mostly imitative. However, this period presented positive dynamization of technological efforts, with the primary goal of increasing productive efficiency and effectiveness, but with additional goals of reducing environmental impacts and meeting regulatory standards.

Keywords: Agribusiness; Food industry; Innovative activity; Technological efforts.

Resumo: *A Indústria Brasileira de Alimentos e Bebidas (IAB) tem uma forte importância social e econômica no cenário nacional, e a tecnologia tem papel fundamental em sua competitividade. Ao estudar aspectos da dinâmica tecnológica da IAB, pretende-se identificar e analisar elementos que incrementem a competitividade do setor. Este trabalho discute a dinâmica tecnológica e inovadora das IBA no período de 2000 a 2011, com base nos indicadores fornecidos pela Pesquisa Industrial de Inovação Tecnológica (PINTEC). Os resultados permitem afirmar que prevalece no setor o caráter incorporador em detrimento do gerador de novas tecnologias. O investimento em P&D das firmas ainda é relativamente baixo, sendo a estratégia tecnológica majoritária do setor a imitativa. No entanto, houve uma dinamização positiva dos esforços tecnológicos nesse período, principalmente a fim de aumentar a eficiência e eficácia produtivas, bem como para reduzir o impacto ambiental e atender às normas regulatórias nacionais.*

Palavras-chave: *Agroindústria; Indústria de alimentos; Atividade inovadora; Esforços tecnológicos.*

1 Introduction and objective

Technology consists of the body of knowledge used for production. It is a key factor in how enterprises interact with their environment and a vital element in the competitiveness of organizations (Rosenthal & Moreira, 1992). The technology employed by enterprises represents one of the main sources of advantage over the competition, and the successful introduction of new technologies results in important increments of competitiveness.

The definition of the innovative nature of a technology varies according to how it is analyzed. New technology is not necessarily new to the market, but can be new to a given enterprise, according to the focus of the analysis conducted (Gonçalves & Gomes, 1993, p. 109). Rosenthal and Moreira (1992, p. 155) defined technological innovation as

> [...] the application of a new body of knowledge to the production process, which results in a new product or changes to an old product's features and/or in the product's level of acceptance in the market.

Thus, according to Carvalho and Furtado (2013, p. 48-49), the intensification of technological and innovative dynamics can be understood as

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> […] a positive and simultaneous evolution of indicators of innovative efforts and outcomes, also involving the establishment of technological strategies that present more offensive or defensive trends and are less dependent or imitative.

De Paula & Bastos (2009) emphasized that, in the agribusiness sector, conquering new spaces in the international market is directly dependent on the innovative capacity of agents and the level of coordination between the supporting industries that contribute to innovation in the sector (packaging, additives, machines and equipment, information technology, etc.). Consequently, the challenges for the food and beverage industry lie in the need to combine scaling gains with product differentiation to aggregate value and reach segmented markets. In 1984, Pavitt (1984) had already classified the food industry as "scale-intensive."

The constant growth in global competition and increasingly stringent consumer demands for variety, convenience, and quality pressure the food and beverage industry to differentiate their products and increase the quality of their innovation processes. Pressure also arises from the need to ensure food safety and the nutritional quality of products, coupled with the biotechnological revolution and all the new processing possibilities that it provides (Fortuin & Omta, 2009).

Furthermore, it is worth remembering that the low complexity of food processing technologies makes them more vulnerable to imitative processes and reduces their appropriability (Sidonio et al., 2013). The sector is characterized by significant absence of technological product disruptions. As will be seen below, the majority of the technological advances in the sector are incremental and developed internally. Technological disturbances are usually tied to new process and management technologies, since these are developed by industries that support agroindustrial businesses.

De Mori (2011) maintained that research about technological standards and technical changes in agroindustrial production systems promotes understanding of the evolution of sectoral dynamics, enabling companies to monitor and guide strategic activities related to science, technology and innovation. Among other things, such investigations can help define indicators and parameters for analyzing the competitive positioning of enterprises in terms of their technological strategies. It is important to take into consideration the specificities presented by each sector relative to technological development and evolution processes, because the characteristics inherent to the productive process and the profiles of end products determine technological intensity and dynamism.

The food and beverage industry is of great importance to the Brazilian economy, in addition to playing a key role in food processing and provision. In this context, the aim of the present article was to describe and analyze the technological and innovative dynamics of food and beverage enterprises between 2000 and 2011, using data from the Industrial Survey of Technological Innovation (*Pesquisas Industriais de Inovação Tecnológica* – PINTEC), conducted by the Brazilian Institute of Geography and Statistics (IBGE). This sector corresponds to section 15 of version 1.0 (applied until 2007) and the sum of sections 10 and 11 in version 2.0 (applied from 2007 to the present) of the National Classification of Economic Activities in Brazil.

The rest of this article consists of five sections. The second section presents information about the food and beverage sector worldwide, with a focus on its main innovation strategies in a global context of changes in competition and competitiveness. The third section discusses the food and beverage sector in the current period of the Brazilian economy, presenting figures on its evolution and representativeness. The fourth section addresses methodology, while the fifth presents the main analyses of the innovation indicators for food and innovation enterprises in Brazil. The sixth section contains final considerations.

2 Technological aspects of the food and beverage sector

Innovation is defined as the process by which enterprises develop and implement new ideas and inventions in the form of goods and services, regardless of whether they are new to their competitors (Cassiolato & Lastres, 2000). According to the Oslo Manual on collecting and interpreting innovation data (FINEP, 2005), innovation activities include all scientific, technological, organizational, financial, and commercial steps that effectively lead, or are intended to lead, to the implementation of innovation. In general terms, such activities aim to improve enterprise performance and can include the development and implementation of new products and processes, new methods for promoting and selling products and changes in organizational practices and structure

According to De Mori (2011), acting upon the technological innovation processes of agribusiness enterprises, which include food and beverage enterprises, requires assessment of the technological creation, diffusion, and incorporation processes in the sector or sectors in which they operate. The author emphasizes that understanding the dynamics and technical changes of a given sector allows the identification of technological bottlenecks, generating data for enterprises, sectors and governments that

seek to enhance the productivity and competitiveness of their activities.

Proença (1996) considered technology to be an essential factor in the development of competitiveness. Along the same lines, addressing the formation of competitive advantage in a global context, Porter (1990) emphasized that technology can overcome the influence of the elements of standard economic theory (capital, labor, and land) on determining competitiveness, because technological innovation is the true and sole source of competitive advantage for firms. However, new technologies should not represent the main source of competitive advantage for enterprises, as they may be accessible to the competition. To sustain competitive advantage, enterprises must accumulate competencies based on new technologies that are difficult for competitors to imitate (Barbosa, 2009). In general, the most common effects and objectives of technological innovation include: increased productivity, better use of raw materials, improved products (aggregated value and increased contribution margin), saving resources, and reducing work-related hazards and accidents (Rodrigues & Ornellas, 1987, p. 28). Gonçalves (1994, p. 70, 81) listed other possible positive effects of innovation within organizations, such as improved agility of client service, modernized processes, and the exploration of new market segments. Tushman & Nelson (1990, p. 2) demonstrated that technology and technological innovations can be considered sources of uncertainty for companies. They present challenges that can alter their internal characteristics, impacting competition, investment, and profitability.

For Jamrog (2006), the most significant drivers of innovation among enterprises are: consumer focus, teamwork, adequate resources, and organizational communication. Other important factors include the ability to select promising ideas and freedom to innovate. In contrast, insufficient resources and absence of formal innovation strategies, in addition to excessive administrative regulations, are the greatest barriers to the success of innovation processes.

A study by Batterink et al. (2006) indicated that food enterprises with strong market orientation achieve greater success with innovation. In this context, Costa & Jongen (2006) emphasized that the greatest barriers to innovation in the food sector are: (1) lack of concrete directives for the effective implementation of development, aimed end consumers; (2) a sequential approach to the innovation process; and (3) lack of coordination and integration with the R&D sector, marketing activities and enterprise know-how.

Fortuin & Omta (2009) conducted a survey of multinational agrifood enterprises in Holland and found strong pressure for innovation by the retail industry. Unequal distribution of power in the productive chain is one of the most powerful drivers of innovation among agrifood businesses.

In the food and beverage industry, large firms – which are at the frontlines of oligopolistic competition – enjoy greater autonomy in terms of the development of new products and processes. In contrast, a greater number of firms have been behaving as receptors and users of innovation, contributing only marginally to occasional innovative change (De Paula & Bastos, 2009). In this context, Cabral (2001) highlighted that in the food and beverage input sector, there is a predominance of process innovation, usually motivated by issues related to production costs. Product innovation tends to be more incremental and conducted by the food and beverage sector itself, conditioned by the basic properties of food products and by issues related to consumer behavior and market pressures.

In a study of innovative actions of food enterprises based on data from the Community Innovation Survey (CIS), Christensen et al. (1996) identified the main strategies associated with innovative processes. According to the authors, enterprises in the sector use offensive innovation strategies when they are first-comers to the market, giving them an important advantage in achieving technological leadership. In turn, defensive strategies enable enterprises to eliminate high levels of uncertainty by developing or redesigning products that have been introduced by others. In terms of market positioning, enterprises with defensive strategies accept being behind first-comers, and use their experience to benefit from mistakes and react according to market responses, especially those related to product differentiation.

According to Fuller (1994), product development in the food industry can be divided into seven classes: (1) line extensions, (2) repositioned products, (3) new forms of existing products, (4) reformulation of existing products, (5) new packaging of existing products, (6) innovative products, and (7) creative products. The most common were repositioning, reformulation and repackaging. This may be associated with the "know-how" profiles of a significant number of food industries, whose origins lie in family enterprises. The technological options used by these industries are aimed predominately at increasing productivity, reducing costs, and adapting products to satisfy specific consumers within a mature market, objectives that usually use the development classes mentioned above as elements to help define strategies.

The ratio of R&D investment to sales in the food industry is relatively low compared to that of other industries. In general, research activities are not considered important assets for innovation in the sector. However, the emergence of new technological paradigms in the food processing industry has driven enterprises to develop in-house research, or even contract development through independent enterprises

or institutions, increasing expenditures for R&D on one side and technological capacity on the other (Cabral, 2007). Technological capacity has been defined by De Mori (2011, p. 70) as a

> […] set of efforts, skills (operative, organizational, and relational) and knowledge, anchored in a constant flow of necessary learning to absorb, use, adapt, develop, and transfer technologies.

The food and beverage sector in Brazil and abroad presents equally low levels of R&D investment, predominately characterized by incremental technological advances and capital technologies (Cabral, 2007). Thus, the innovative process of the food industry is characterized by extensive, intensive, and intricate technological interfaces with other industries that develop innovations throughout the productive process, starting with the raw material segment (agriculture and livestock) and extending up to the factors of production and capital goods. Significant innovation occurs primarily in the field of ingredient and additive formulation, functional foods, transgenics, and packaging.

Santini et al. (2005) emphasized that the innovative process in the Brazilian food industry follows four distinct patterns: 1) adaptation of products and processes by multinationals (generated in international matrixes or adapted by national subsidiaries); 2) national innovations that mirror the external markets (copies or imitations of existing international products, generally created by large or medium national enterprises); 3) innovations that mirror the national market (copies or imitations of products and processes of large national enterprises, carried out by smaller enterprises with regional operations); and 4) genuinely national innovations (very rare and usually introduced by enterprises with strong know-how and financial capacity).

Still on the topic of innovation in the sector, De Mori (2011) highlighted the importance assigned to hygiene and sanitary requirements, regulations, and standards regarding the production and commercialization of food products, at both the national and international levels. In this sense, innovation is commonly found in organizational aspects, such as the implementation of good manufacturing practices and hazard analysis and critical control points (HACCP). According to this author, product shelf life and long transport time to reach consumers demand logistical innovation, in terms of organizational and marketing processes. These observations are important, since they indicate that to develop competitiveness in the food and beverage industry, innovation in management technologies must be coupled with product and process innovation.

On the innovation potential of the food industry, Christensen et al. (1996) demonstrated that incremental changes in products and processes require less R&D support and are more likely to be protected by patents when compared to radical innovations observed in high-tech industries. According to the authors, innovations in the food and beverage industry are isolated events and are the result of open-ended processes – evolutionary processes in which it is difficult to establish a beginning and end point in time. In the sector, technological innovations result from open and revolutionary processes and daily learning, together with elements of incrementalism. Imitative processes are widely used, since it is easy to obtain information about competitors and costs relative to barriers to entry are not high.

Domingues (2008) conducted a study of the technological behavior and dynamics of the Brazilian food and beverage sector between 1998 and 2005 based on data from PINTEC. The results showed that even though the rate of innovation in the food industry was close to the national manufacturing industry average, indicators of effort were low. This means that innovation is due much more to technology acquisition, especially machines and equipment, than to in-house technological development. The research also shows that the sector's dominant strategic behavior is clearly directed at imitative strategies, meaning that enterprises rarely introduce radical innovation, but rather imitate products developed by others. Being part of a given market and deriving benefits from special legislative conditions or public sector demands provide certain advantages, through greater distribution channels and market facilities.

3 The Brazilian agribusiness sector

The food industry in Brazil plays a leading role in the national and economic settings. Given the growth of internal and external demands, food and beverage producers have invested in productive capacity and efficiency. According to IBGE data, the food and beverage segment produces the highest employment in the country, considering all the people involved in industrial production, accounting for approximately 20% of employment in all manufacturing activities. In 2014, the industry employed 1.66 million workers, 92% higher than in 1992 (ABIA, 2015), as Table 1 shows.

According to data from IBGE and the Brazilian Association of Food Industries (ABIA, 2015), the food and beverage industry accounts for 10% of the national GDP and 22% of the country's industrial GDP. Still according to ABIA data, the revenue of enterprises in the sector totaled almost BRL 526 billion in 2014: BRL 424.5 billion in food products and BRL 101.2 billion in beverages. This performance places the sector in the position of having the highest gross production value in the manufacturing industry.

In 2014, the sector exported the equivalent of BRL 96.9 billion in food and beverages, 18.3% of Brazil's exports. Furthermore, food imports were less important and were concentrated in wheat, totaling

Table 1. Brazilian food and beverage industry: main economic indicators (200-2011).

	2000	2005	2010	2011	2012	2013	2014
Mean occupation of installed capacity (%)	73.3	72.6	71.3	74.5	72.5	71.5	71.1
Number of employed persons in the sector (thousands)	872.0	1,206.2	1,527.3	1,583.7	1,585.6	1,643.8	1,660.0
Participation of employment in the manufacturing industry (%)	18.4	19.7	19.4	19.5	19.5	19.7	20.4
Participation in total imports	2.9%	2.0%	2.3%	2.4%	2.5%	2.4%	2.5%
Imports of industrialized food - billions (BRL)	3.0	3.6	7.2	9.2	11.0	12.4	13.5
Participation in total exports	13.9%	16.9%	18.7%	17.5%	17.9%	17.8%	18.3%
Exports of industrialized food - billions (BRL)	14.0	48.9	66.7	75.0	84.8	92.8	96.9
Revenue (net of direct tax)	100.2	184.2	330.6	383.3	431.9	484.7	525.8
Participation in national GDP (%)	9.1	9.5	8.8	9.3	9.8	10	10.2
Participation in the GDP of manufacturing industry (%)	18.5	16.1	19.5	20.3	20.8	21.3	22.5

Source: ABIA (2015).

BRL 13.5 billion. This makes the food industry one of the most relevant in generating a positive balance of trade, which reached USD 83.4 billion in 2015. This was much higher than the balance of trade of the Brazilian economy as a whole, which was negative USD 4 billion (ABIA, 2015).

Considering the sector's high competitiveness and the growth in consumption of greater aggregated value products, higher levels of technology and management are demanded from firms. According to ABIA data, in 2012, 75% of the food consumed in Brazil underwent some form of industrial processing, against 70% in 1990 and only 56% in 1980. New market niches are also growing, boosting product differentiation strategies. Products related to health and well-being (diet, light, functional, fortified, natural and healthy foods) are a good example of this trend toward strategic product differentiation. In 2012, this segment obtained BRL 38.4 billion in revenue, corresponding to 8.9% of the total food sales in the country. It is also worth mentioning that in most cases, differentiated products are more demanding in terms of product and process technologies.

4 Methods

The present study employed two methods. First, a literature review was conducted on innovation and the characteristics of the innovation process that encompassed the specificities of the food industry. This review also included a survey of sectoral, national and international studies about the food and beverage industry. This information enabled the creation of a brief characterization of the Brazilian industrial food and beverage sector, emphasizing and justifying its importance in Brazil.

The second technique consisted of processing secondary data obtained through the Industrial Survey of Technological Innovation, conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2002, 2005, 2007, 2010, 2013) in 2000, 2003, 2005, 2008 and 2011, all made available by the institute. Data from the manufacturing industries responsible for producing food and beverage products were analyzed in terms of product and process innovation, levels of novelty and main impacts. The intensity of expenditures of these industries and their main cooperative relationships, among other factors, were also scrutinized in these analyses.

The main limitations found in this analytical exercise were related to variations in the nomenclature of variables used by IBGE throughout the years, especially between the 2005 and 2008 editions. The absence of some data in the 2000 publication was also observed. However, these limitations did not compromise the breadth and pertinence of the analyses.

5 The technological dynamics of the food and beverage industry

5.1 Technological efforts in the food and beverage industry

As highlighted above, innovation in the food and beverage industry shows strong relationships with its supporting industries - those producing packages, additives, and machinery and equipment, - especially in terms of process innovation, since product innovation is conducted for the most part by the food and beverage industry itself. Nonetheless, Carvalho & Furtado (2013) maintained that the technological independence of the

industry abroad has been increasing in relation to its traditional technology suppliers, i.e., more process innovation has been developed within the food and beverage industry itself. The authors noted that a similar trend has been occurring in Brazil.

Table 2 shows the big difference between product and process innovations in terms of the main agents responsible. Product innovations are mainly developed inside the food and beverage industry, reaching over 80% of the total in 2011. Those that arise from cooperative relationships with other enterprises or institutions, or are acquired from other enterprises or institution, are considerably less frequent. In turn, process innovation is mainly developed and acquired from sources external to the food and beverage industry. However, since 2003, there has been considerable growth in process innovations conducted internally. This reveals some growth in the technological independence of firms in the sector from their supporting industries, which have traditionally developed technology for the sector

Up to 2005, there was an increase in the internalization of innovative product activities by enterprises. However, after 2005, these rates decreased. In contrast, process innovation, which usually involves higher levels of technological capacity (De Mori, 2011), underwent a shift from relying on external agents to agents within the food and beverage industry itself, reflecting investments made in the sector.

Total investments by the food and beverage sector in innovation decreased 15% between 2008 and 2011, reaching 2.05% of the revenue of innovative enterprises that year. Figure 1 demonstrates the amount of net revenue targeted toward various innovative activities by innovative firms.

The acquisition of machines and equipment was the most important innovative activity in all

Table 2. Main agents responsible for product/process development among innovative enterprises – Brazilian food and beverage industry (2000-2011).

Main agents responsible for innovation	Product innovation					Process innovation				
	2000	2003	2005	2008	2011	2000	2003	2005	2008	2011
The enterprises	75.3%	88.7%	89.8%	78.7%	83.7%	7.5%	4.7%	5.6%	13.0%	14.5%
Another enterprise within the group	1.4%	0.8%	0.9%	1.4%	0.5%	0.6%	0.1%	0.3%	0.5%	0.3%
The enterprises in cooperation with other enterprises or institutions	12.2%	6.0%	4.3%	7.2%	5.4%	5.8%	3.6%	3.0%	3.9%	10.3%
Other enterprises or institutions	11.2%	4.5%	5.0%	12.6%	10.4%	86.1%	91.5%	91.0%	82.6%	74.9%
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: IBGE (2002, 2005, 2007, 2010, 2013).

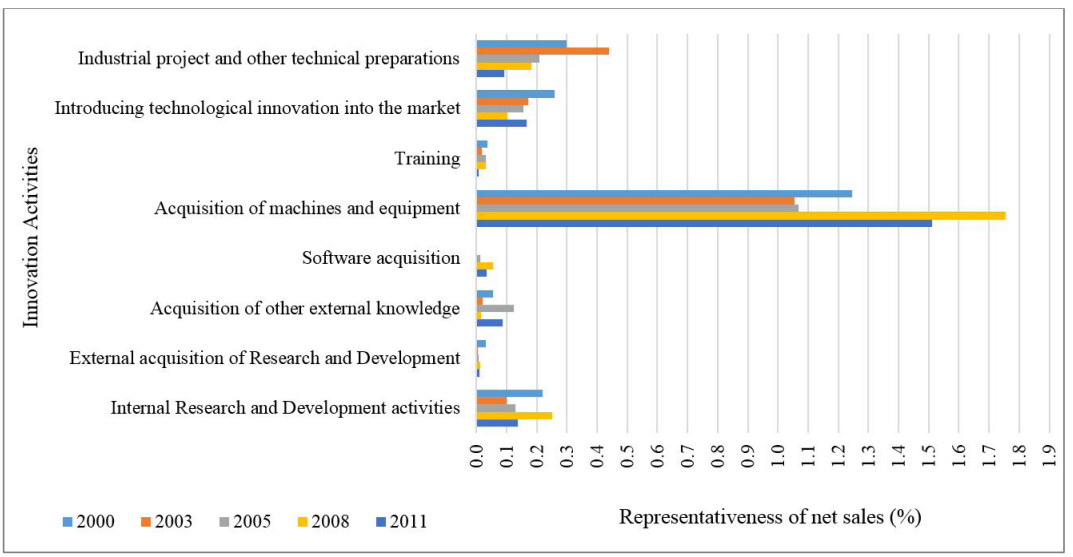

Figure 1. Intensity of expenditure on innovation activities among innovative enterprises – Brazilian food and beverage industry (2000-2011). Source: IBGE (2002, 2005, 2007, 2010, 2013). Note: "Software Acquisition" data were made available from 2005 onwards.

the analyzed periods, reaching 1.51% of enterprise revenue in 2011. However, this variable presented the greatest drop between the two most recent surveys. The growth in introduction of technological innovation in the market, such as the acquisition of external knowledge, grew 0.7% between 2008 and 2011, the highest in the period. Observation of the rates of external knowledge acquisition for innovation and acquisition of machines and equipment for the same purpose suggest that there was a decrease in efforts towards innovative independence of firms between 2008 and 2011.

These facts may be a reflection of recent government policies, which have encouraged cooperation of enterprises and universities with research institutes to boost their innovative processes. Furthermore, the open innovation model, in which enterprises receive contributions from external partners (clients, suppliers, universities and even competitors) throughout the innovative process, has been increasingly adopted by enterprises.

Table 3 demonstrates the growth in the number of employed persons in internal R&D activities of innovative enterprises, in absolute and relative terms, between 2008 and 2011. Between 2005 and 2008, the strong increase observed in machine and equipment acquisition, coupled with the absolute growth in individuals working in the food industry, reduced the intensity of employed persons in R&D activities. This indicator was obtained by dividing the total number of employed persons (in full personnel equivalents) by the total number of employed persons in the sector.

This finding is in agreement with the fact that the food and beverage industry has been increasingly developing internal innovative activities. An explanation for this scenario could be the increase in productivity of food and beverage employed personnel involved with R&D. However, the data provided by the IBGE is not sufficient to confirm this supposition.

Since 2005, the importance of information and research networks as sources of information for innovation development has grown. Technological advances in terms of information technology, in addition to the importance of licensing and patents and testing, trial and certification institutions, explain and justify this situation. Still on the topic of the main sources of information for innovation development, Figure 2 shows that, together with other enterprise areas, clients and suppliers stand out as strong sources of information on innovative activities in the food industry.

Between 2005 and 2008, some sources of information external to enterprises (fairs, conferences, centers of professional training, universities, etc.) grew in importance, similar to internal sources, such as R&D

Table 3. Persons employed and intensity of employed personnel in R&D – Brazilian food and beverage industry (200-2011).

	2000	2003	2005	2008	2011
Total employed persons	912,533	1,038,763	1,263,474	1,308,081	1,710,348
Employed persons in R&D	3,451	1,951	2,905	2,422	3,603
Intensity of employed persons in R&D	0.38%	0.19%	0.23%	0.19%	0.21%

Source: IBGE (2002, 2005, 2007, 2010, 2013).

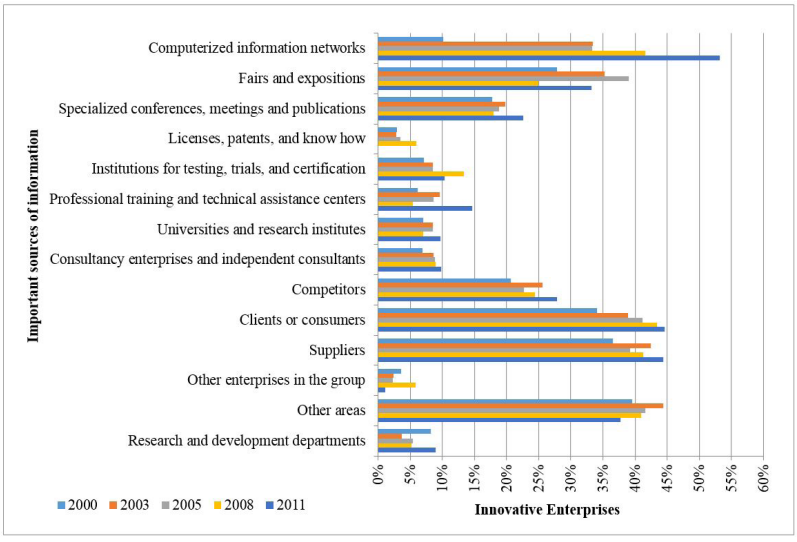

Figure 2. Important sources of information for innovative enterprises – Brazilian food and beverage industry (2000-2011). Source: IBGE (2002, 2005, 2007, 2010, 2013).

departments. This data indicate that the sector is strongly involved in local innovation systems, given that national sources of information have grown progressively in importance, as indicated by most of the categories in Table 4.

After a considerable drop between 2000 and 2005, levels of cooperation for innovation increased significantly from 2005 and 2011, reaching 17.8% that year. Cooperation aimed at technological development can promote quicker innovative processes. Tus, the growth perceived in this last period could be a reflection of increased competitiveness in the sector, which drives more aggressive market behavior by enterprises.

Figure 3 presents cooperative relationships with other organizations for innovation of the researched enterprises. Changes can be observed in terms of the importance of these organizations, with emphasis on the percentage growth in the importance of testing institutions, universities, and clients between the two most recent surveys. This demonstrates efforts to acquire qualified human resources to undertake innovative activities, an important aspect of reducing the risks involved in innovation development.

Historically, suppliers have been the main cooperative agents for innovation in the food industry. This is a reflection of the already mentioned multiple interfaces of the innovation process in this industry.

5.2 Results of innovative activities in the food and beverage industry

The increasingly important role of innovation in the competitive strategies of food enterprises is reflected in the growth of its innovation rates. The number of enterprises considered innovative in the food and beverage sector grew more than 10% between 2000 and 2011. However, during this period, the diversity of enterprise innovative activity decreased. There was also a significant reduction in the percentage of enterprises that innovated in both products and processes. Between 2008 and 2011, the number of enterprises that carried out only product innovation activities decreased, while the number of those that carried out only process innovation increased (see Table 5).

Regarding the range of these innovations, the high percentage of processes and products new to enterprises (more than 85% in both cases) is worth emphasizing. This contrasts with the low innovation rate considered new, not only to the enterprise in question, but also to the national market. These data

Table 4. Location of information sources for innovation: Brazilian food and beverage industry (2000-20110 (%).

Sources of information for innovation	Location	2000	2003	2005	2008	2011
Other enterprises in the group	Brazil	4.2	2.4	2.7	7.7	3.6
	Abroad	1.5	1.5	1.6	1.6	2.4
Suppliers	Brazil	64.5	69.2	70.2	73.8	69.0
	Abroad	7.5	3.0	4.0	3.2	7.0
Clients and consumers	Brazil	60.9	60.5	66.1	74.3	76.4
	Abroad	1.4	2.4	1.2	0.9	0.5
Competitors	Brazil	55.5	51.0	57.3	64.8	71.9
	Abroad	1.7	0.9	0.9	1.4	0.6
Consultancy enterprises and independent consultants	Brazil	16.4	22.0	24.4	26.6	39.4
	Abroad	1.1	0.6	0.4	0.2	0.2
Universities and research institutes	Brazil	21.2	16.8	22.2	20.7	30.6
	Abroad	0.5	0.1	0.1	0.1	0.1
Professional training and technical assistance centers	Brazil	24.4	19.4	22.3	14.8	38.3
	Abroad	0.3	0.1	0.0	0.1	0.1
Institutions for testing, trials, and certification	Brazil	19.4	16.1	25.1	33.3	33.4
	Abroad	0.2	0.1	0.1	0.1	0.2
Acquisition of licenses, patents, and know how*	Brazil	9.0	3.7	6.2	23.3	-
	Abroad	0.9	0.6	0.5	0.2	-
Specialized conferences, meetings and publications	Brazil	40.6	41.6	41.4	38.9	50.7
	Abroad	6.0	2.8	2.4	2.8	3.0
Fairs and expositions	Brazil	55.0	61.5	60.7	58.2	59.6
	Abroad	8.1	4.1	3.8	3.7	3.8
Computerized information networks	Brazil	31.3	47.4	61.1	65.3	77
	Abroad	5.7	4.5	4.8	3.0	5.7

*Data not presented in PINTEC 2011. Source: IBGE (2002, 2005, 2007, 2010, 2013).

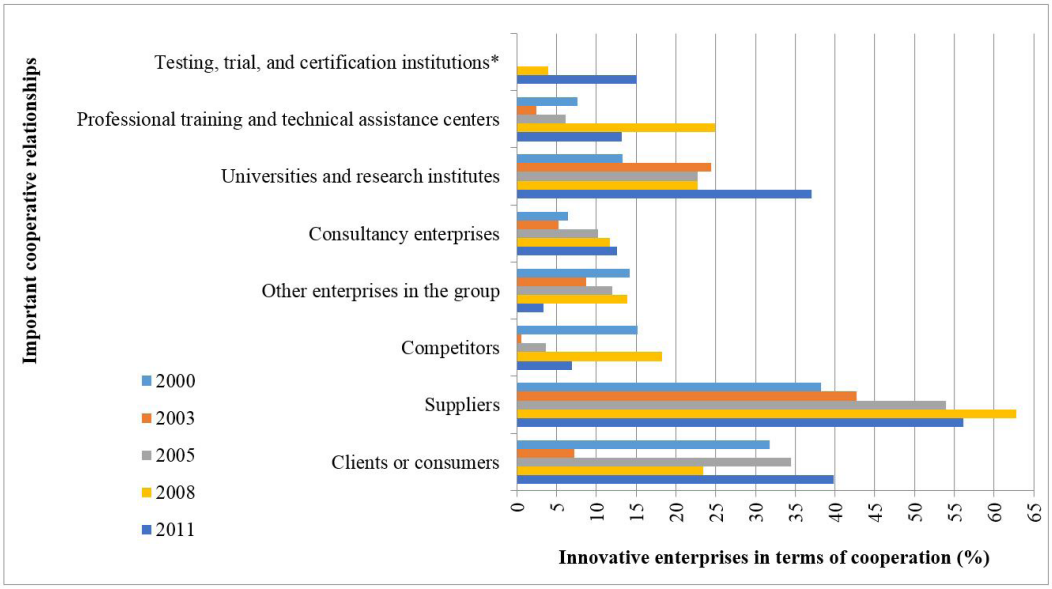

Figure 3. Most important cooperative relationships for innovative enterprises – Brazilian food and beverage industry (2000-2001). Source: IBGE (2002, 2005, 2007, 2010, 2013). *Data available since PINTEC 2008.

Table 5. Enterprises with product and process innovation, by range of innovation carried out – Brazilian food and beverage industry (2011-2011) (%).

Rate of innovation	2000	2003	2005	2008	2011
Innovative enterprises	29.5	33.6	32.5	38.0	40.1
Types of innovation					
Product and process innovation	40.2	42.0	42.8	47.6	31.5
Only product innovation	15.4	17.0	20.8	18.1	15.9
Only process innovation	44.3	41.0	36.4	34.3	52.6
Total	100.0	100.0	100.0	100.0	100.0
Range of innovation					
Product new to the enterprise	92.3	88.3	87.7	89.8	85.3
Product new to the national market	13.9	13.0	13.2	16.4	17.9
Process new to the enterprise	91.1	98.7	95.3	93.0	96.0
Process new to the national market	12.8	2.0	6.5	8.8	4.9

Source: IBGE (2002, 2005, 2007, 2010, 2013).

suggest that many innovations are incremental or are imitations/copies of products that already exist in the Brazilian market, corroborating the results of Domingues (2008). Table 6 illustrates this growth in the imitative process for both foreign and national products and processes.

Despite this scenario, between 2005 and 2008, the number of enterprises with patenting activities increased (Figure 4). Carvalho & Furtado (2013) emphasized that patent protection in the food and beverage industry is very expensive, due to high turnover rates and high levels of differentiation inherent in products. Thus, the most common innovation protection methods used by enterprises are still brands and industrial secrets, which promote greater appropriability and profitability, in addition to traditional approaches focused on strengthening customer loyalty.

The main drivers of enterprise innovation are related to the perceptions of the impact of innovations on their business. Figure 5 shows that between 2008 and 2011, concerns about the consumer market grew considerably, given the growth in variables related to broadening the range of products offered, maintaining and expanding enterprise participation in the market, and openness to new markets. Other concerns were related to productive capacity, cost production reductions, and reduction of environmental impacts. Investments linked to production were in accordance with the increase in investments in machines and equipment observed previously, in addition to the importance given to suppliers and sources of information for innovation.

Table 6. Level of novelty of main products/processes of innovative enterprises – Brazilian food and beverage industry (2000-2011) (%).

Type of innovation	Level of novelty	2003	2005	2008	2011
Product	Improving an already existing product	33.4	50.7	49.0	43.5
	New to the enterprise, but already present in the national market	60.1	48.0	44.0	53.7
	New to the national market, but already present in the global market	6.1	1.2	6.6	2.4
	New to the global market	0.4	0.1	0.3	0.4
	Total	100.0	100.0	100.0	100.0
Process	Improving an already existing process	52.5	72.5	58.2	68.0
	New to the enterprise, but already present in the national market	46.9	27.0	34.6	30.7
	New to the national market, but already present in the global market	0.6	0.5	7.1	1.3
	New to the global market	0.1	0	0.1	0.1
	Total	100.0	100.0	100.0	100.0

Source: IBGE (2002, 2005, 2007, 2010, 2013).

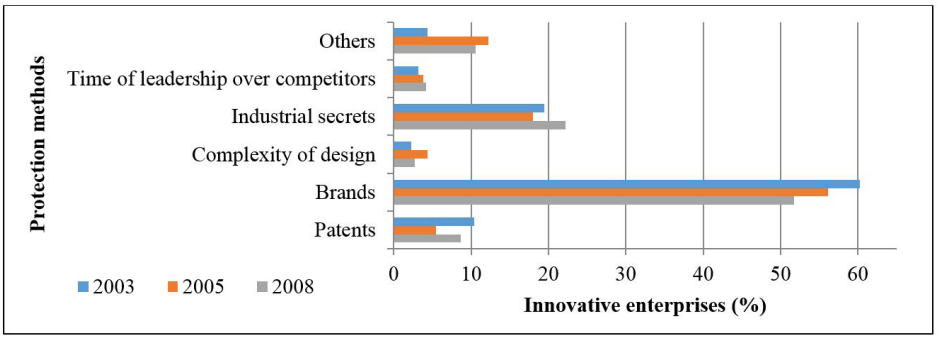

Figure 4. Protection methods employed by innovative enterprises – Brazilian food and beverage industry (2000-2011) (%). Source: IBGE (2005, 2007, 2010).

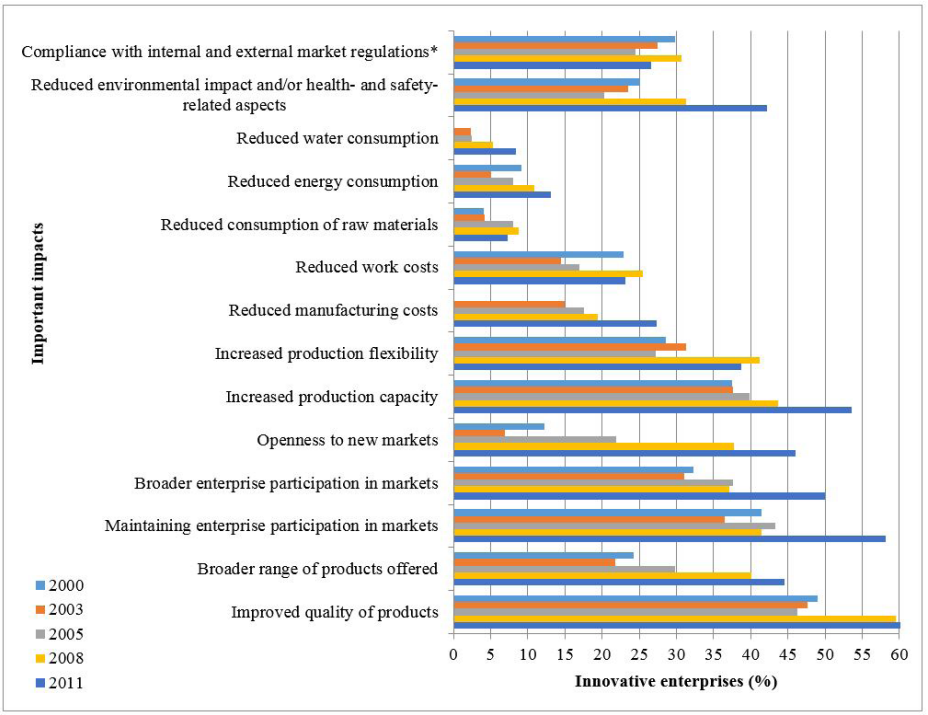

Figure 5. Important impacts of innovation – Brazilian food and beverage industry (2000-2011) (%). Source: IBGE (2002, 2005, 2007, 2010, 2013). *Note: In PINTEC 2008, the data on "compliance with internal and external market regulations" were combined.

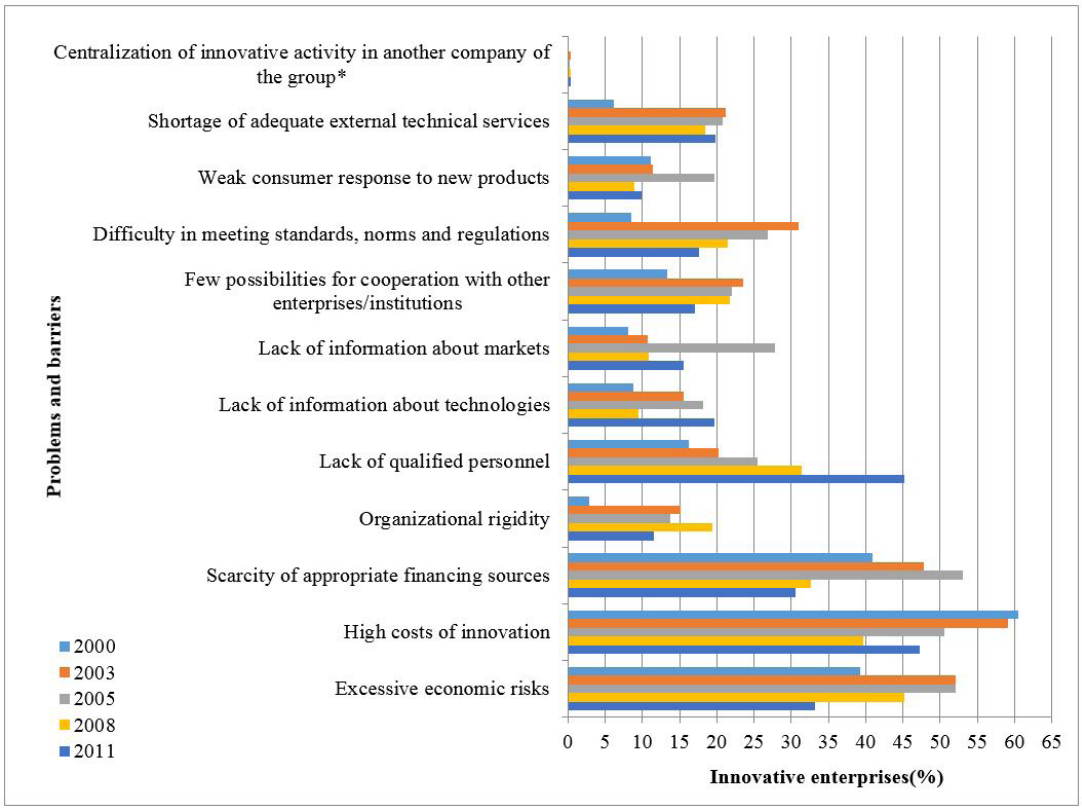

Figure 6. Most important problems and barriers related to innovation – Brazilian food and beverage industry (2000-2011) (%). Source: IBGE (2002, 2005, 2007, 2010, 2013).*Data not present in PINTEC 2000.

Figure 6 presents the main problems and barriers faced by the Brazilian food and beverage industry in their innovation processes. Most of these negative factors diminished between 2008 and 2011. This situation reflects a more favorable environment for innovation, promoted primarily by tax incentive policies and improvements to ensure appropriability and return on innovations (Law of Innovation), which have been in force since 2004.

Greater availability of tax incentives and greater guarantee of return on investment may be reflected in less concern about scarcity of financing sources and excessive economic risks (Figure 6). The growth of consumer demand for new products with higher aggregate value can be confirmed by reduced concerns with possible weak responses to the launch of these products in the market in 2005. In contrast, the issue of shortages of qualified personnel grew considerably, which reflects the national need to invest in education and quality training.

6 Final considerations

Through selected data from the PINTEC survey (2000 to 2011), the aim of the present study was to conduct an in-depth analysis of specific aspects of the technological dynamics of the food and beverage industry. The food and beverage sector is of essential social and economic importance in Brazil, accounting for 10% of the national GDP and 20% of the manufacturing industry's GDP. However, the sector still presents intrinsic weaknesses in technology and innovation, defined as new products, processes or services, which are of recognized importance to maintaining competitive advantage and satisfying consumer needs (Menrad, 2004).

Increasing innovation rates in the food industry reflect efforts to improve processes and products, with greater emphasis on processes. Nonetheless, most innovations are new only to enterprises, which in one sense indicates the sector's low technological capacity. This situation demonstrates that the generation of technological knowledge in the food and beverage sector has been low in recent years. Even though the number of innovative enterprises has been growing, the number of enterprises that perform simultaneous process and product innovation has been decreasing, indicating the continuing trend toward incremental efforts by the food and beverage industry. This suggests restraint in product line expansion and adding value, since new products require significant modifications to

production processes and intensify the technological dynamics of the food industry.

In general, the indicators show that the sector still behaves much more as an incorporator than as a creator of technology and innovation. Strong investments in machine and equipment acquisition show that the sector acquires more external technology than it develops. The undesirable situation of technological dependence on suppliers is shown by: the low percentage of employed personnel in enterprise R&D departments; the importance of clients, suppliers and competitors as sources of information for innovation; and the fact that innovations are only new to the enterprises, since a majority are only improvements of already existing products and/or processes.

In this context, the fact that the technological strategies of the food and beverage sector are still overwhelmingly imitative is illustrated by: relatively low levels of investment in R&D; the growing importance of computerized networks as sources of information for development, which indicates that enterprises are searching for information about the market and technology; the mostly incremental nature of products and processes; and the importance of the technological impact on aspects related to productive effectiveness and efficiency.

However, dynamization of technological efforts increased between 2008 and 2011, especially within the scope of new process development, in addition to greater internalization. Expenditures on internal R&D activities grew considerably, as did the representativeness of national sources of information for innovation development. Additionally, between 2005 and 2008, use of patents as a protection method grew, which means that new knowledge that warrants protection was created for the industry.

In the same period, efforts were made to improve the food sector's productive effectiveness and efficiency, especially by reducing manufacturing costs, and maintain its image in the market through innovative efforts. Among other things, the growth in these efforts reflects an improved institutional environment for technological development, provided by incentive laws that have been in force since 2004. Thus, even with its imitative innovative characteristics, the food and beverage industry has shown greater interaction with the national innovation system and involvement with various agents, generating technological learning and contributing to the results of the sector's innovative activities.

Strong technological, economic, political, and institutional trends have been transforming the food production system through information and communication technologies, biotechnology, research and development systems, globalized agrifood chains, direct foreign investment and international trade (Caiazza et al., 2014). In this context, more promising improvements to the sector's competitiveness can be reached via greater investments in R&D, which increase the innovative performance of enterprises and, consequently, promote internal development of technologies and innovations. The usual focus on cost reduction or production process efficiency alone can place pressure on the industry's long-term competitive advantage (van Galen et al., 2013).

More integrated and efficient open innovation models could also be explored (Bigliardi & Galati, 2013) by intensifying systematic collaboration with universities and other research centers. Furthermore, Flipse et al. (2014) stated that the increasing interest of consumers and enterprises in more sustainable, responsibly produced products drives enterprises to adopt socially responsible innovation practices, with the goal of differentiating their portfolio in terms of sustainability, health, safety and social equity.

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References

Associação Brasileira das Indústrias de Alimentos – ABIA. (2015). *O setor em números*. São Paulo: ABIA. Recuperado em 21 de outubro de 2015, de http://www.abia.org.br/anexos/FichaTecnica.pdf

Barbosa, A.P.R. (2009). *A formação de competências para inovar através de processos de transferência de tecnologia: um estudo de caso* (Tese de doutorado). Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Batterink, M. H., Wubben, E. F. M., & Omta, S. W. F. (2006). Factors related to innovative output in the Dutch agrifood industry. *Journal on Chain and Network Science*, 6(1), 31-45. http://dx.doi.org/10.3920/JCNS2006.x063.

Bigliardi, B., & Galati, F. (2013). Models of adoption of open innovation within the food industry. *Trends in Food Science & Technology*, 30(1), 16-26. http://dx.doi.org/10.1016/j.tifs.2012.11.001.

Cabral, J. E. O. (2001). *Natureza da inovação tecnológica na indústria de alimentos do Brasil*. Fortaleza: Embrapa Agroindústria Tropical. Recuperado em 18 de outubro de 2014, de http://pessoal.utfpr.edu.br/sant/arquivos/Natureza%20da%20inovacao%20na%20Industria%20de%20Alimentos.pdf

Cabral, J. E. O. (2007). Determinantes da propensão para inovar e da intensidade inovativa em empresas da indústria de alimentos do Brasil. *Revista de Administração Contemporânea*, 11(4), 87-108. http://dx.doi.org/10.1590/S1415-65552007000400005.

Caiazza, R., Volpe, T., & Audretsch, D. (2014). Innovation in agro-food chain. *Journal of Enterprising Communities: People and Places in the Global Economy*, 8(3), 180-187. http://dx.doi.org/10.1108/JEC-06-2014-0009.

Carvalho, S.A.D., & Furtado, A.T. (2013). Estratégias tecnológicas e dinâmica de inovação das empresas agroalimentares no Brasil. *Revista Gestão & Conexões*, 2(1), 47-75.

Cassiolato, J. E., & Lastres, H. M. M. (2000). Sistemas de inovação: Políticas e Perspectivas. *Parcerias Estratégicas*, 8, 237-255.

Christensen, J. L., Rama, R., & Von Tunzelmann, N. (1996). *Innovation in the European food products and beverage industry: Industry studies of innovation using CIS data* (Project 94/111, EIMS Publication, 35). Bruxelles: European Information Monitoring System.

Costa, A. I. A., & Jongen, W. M. F. (2006). New insights into consumer-led food product development. *Trends in Food Science & Technology*, 17(8), 457-465. http://dx.doi.org/10.1016/j.tifs.2006.02.003.

De Mori, C. (2011) *Capacidade tecnológica em sistemas agroindustriais: proposição de índice e aplicação a empresas dos segmentos de trigo e leite* (Tese de doutorado). Universidade Federal de São Carlos, São Carlos.

De Paula, N., & Bastos, L. (2009). Inserção do agronegócio alimentar brasileiro nos mercados mundiais. *Estudos Sociedade e Agricultura*, 17(2), 304-331. Recuperado em 19 de janeiro de 2015, de http://r1.ufrrj.br/esa/art/200910-304-331.pdf

Domingues, S. A. A. (2008). *Indústria de Alimentos e Bebidas no Brasil: uma análise da dinâmica tecnológica e das estratégias de inovação de suas empresas entre 1998 e 2005* (Tese de doutorado). Universidade Estadual de Campinas, Campinas.

Financiadora de Estudos e Projetos – FINEP. (2005). *Manual de Oslo: diretrizes para coleta e interpretação de dados sobre inovação* (3. ed). Rio de Janeiro: FINEP.

Flipse, S., van der Sanden, M., Fortuin, F. T. J. M., & Omta, S. W. F. (2014). Enhancing responsible innovation in Food Industry. In *Proceedings of the WICaNeM 2014*. Wageningen: Wageningen University & Research.

Fortuin, F. T. J. M., & Omta, S. W. F. (2009). Innovation drivers and barriers in food processing. *British Food Journal*, 111(8), 839-851. http://dx.doi.org/10.1108/00070700910980955.

Fuller, W. G. (1994). *New food product development: from concept to marketplace*. Florida: CRC Press.

Gonçalves, J. E. L. (1994). Os impactos das novas tecnologias nas empresas prestadoras de serviços. *Revista de Administração de Empresas*, 34(1), 63-81.

Gonçalves, J. E. L., & Gomes, C. A. (1993). A tecnologia e a realização do trabalho. *Revista de Administração de Empresas*, 33(1), 106-121.

Instituto Brasileiro de Geografia e Estatística – IBGE. (2002). *Pesquisa industrial: Inovação tecnológica 2000*. Rio de Janeiro: IBGE. Recuperado em 30 de julho 2015, de http://www.pintec.ibge.gov.br

Instituto Brasileiro de Geografia e Estatística – IBGE. (2005). *Pesquisa industrial: Inovação tecnológica 2003*. Rio de Janeiro: IBGE. Recuperado em 30 de julho 2015, de http://www.pintec.ibge.gov.br

Instituto Brasileiro de Geografia e Estatística – IBGE. (2007). *Pesquisa industrial: Inovação tecnológica 2005*. Rio de Janeiro: IBGE. Recuperado em 30 de julho 2015, de http://www.pintec.ibge.gov.br

Instituto Brasileiro de Geografia e Estatística – IBGE. (2010). *Pesquisa de Inovação tecnológica 2008*. Rio de Janeiro: IBGE. Recuperado em 30 de julho 2015, de http://www.pintec.ibge.gov.br

Instituto Brasileiro de Geografia e Estatística – IBGE. (2013). *Pesquisa de Inovação 2011*. Rio de Janeiro: IBGE. Recuperado em 30 de julho 2015, de http://www.pintec.ibge.gov.br

Jamrog, J. J. (2006). *The quest for innovation: a global study of innovation management (2005-2016)*. Tampa: University of Tampa.

Menrad, K. (2004). Innovations in the food industry in Germany. *Research Policy*, 33(6-7), 845-878. http://dx.doi.org/10.1016/j.respol.2004.01.012.

Pavitt, K. (1984). Sectoral patterns of technical change: towards a taxonomy and a theory. *Research Policy*, 13(6), 343-373. http://dx.doi.org/10.1016/0048-7333(84)90018-0.

Porter, M. E. (1990). *Vantagem competitiva das Nações*. Rio de Janeiro: Campus.

Proença, R. P. C. (1996). *Aspectos organizacionais e inovação tecnológica em processos de transferência de tecnologia: uma abordagem antropotecnológica no setor de alimentação coletiva* (Tese de doutorado). Universidade Federal de Santa Catarina, Florianópolis.

Rodrigues, I. P., & Ornellas, E. (1987). Influência da tecnologia na estrutura organizacional e eficácia das empresas. *Revista de Administração*, 22(2), 25-29.

Rosenthal, D., & Moreira, I. L. (1992). Algumas considerações sobre a natureza do processo de capacitação tecnológica: "Fontes de inovação. *Revista de Administração Pública*, 26(4), 145-160.

Santini, G. A., Schiavi, S. M. A., & Souza, H. M., Fo. (2005). Inovações tecnológicas em cadeias agroindustriais: alguns casos do segmento de processamento de carnes, leite e café no Brasil. In *Anais do XII Simpósio de Engenharia de Produção – SIMPEP*. Bauru: UNESP.

Sidonio, L., Capanema, L., Guimarães, D. D., & Carneiro, J. V. A. (2013). *Inovação na indústria de alimentos: importância e dinâmica no complexo groindustrial brasileiro*. Rio de Janeiro: BNDES. Recuperado em 30 agosto 2015, de https://web.bndes.gov.br/bib/jspui/bitstream/1408/1512/1/A%20mar37_08_Inova%C3%A7%C3%A3o%20na%20ind%C3%BAstria%20de%20alimentos_P.pdf

Tushman, M. L., & Nelson, R. R. (1990). Introduction: Technology, Organizations, and Innovation. *Administrative Science Quarterly*, 35(1), 1-8. http://dx.doi.org/10.2307/2393548.

van Galen, M., Logatcheva, K., Bakker, T., Oosterkamp, E., & Jukema, G. (2013). *Innovation in the food industry: an internationl benchmark study* (Project code 2273000201). The Hague: LEI Wageningen UR.