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UNLOCKING THE BRAZILIAN POTENTIAL OF FOOD TECHNOLOGIES TO ATTAIN SDG 2 – ZERO HUNGER

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Abstract

Brazil is working towards achieving United Nations Sustainable Development Goal 2 (SDG 2) of Zero Hunger, but reapeared on the world hunger map in 2019-20. This study seeks to identify the technologies existing in Brazil to address food security challenges effectively. A total of 5,084 patents from 45 food technological fields were analyzed in the Worldwide Espacenet database, using the International Patent Classification (IPC), spanning from 2000 to 2019. The key technologies comprise cocoa products, flour/dough, animal food, dairy products, preserved/ripened/canned products, nutritional modification/dietary products, microorganisms/enzymes for food, coffee/tea, sucrose production, new plants, and seafood. Academic patents encompass high-nutritional-value biodiversity products, indicating potential future specialties. Conversely, non-academic technologies mainly revolve around traditional colonial products exported as low-priced commodities.

Keywords: Food. Hunger. Patent assessment. Technological readiness levels, Firms' technological oportunities. SDG2.

DESBLOQUEANDO O POTENCIAL BRASILEIRO DAS TECNOLOGIAS ALIMENTARES PARA ALCANÇAR O ODS 2 - FOME ZERO

Resumo

O Brasil está trabalhando para alcançar o Objetivo de Desenvolvimento Sustentável 2 (ODS 2) das Nações Unidas, de Fome Zero, mas voltou a figurar no mapa mundial da fome em 2019-20. Este estudo busca identificar as tecnologias existentes no Brasil para enfrentar os desafios de segurança alimentar de forma eficaz. Um total de 5.084 patentes de 45 campos tecnológicos alimentares foram analisadas no banco de dados Worldwide Espacenet, utilizando a Classificação Internacional de Patentes (CIP), abrangendo o período de 2000 a 2019. As principais tecnologias incluem produtos de cacau, farinha/massa, alimentos para animais, produtos lácteos, produtos preservados/maturados/enlatados, modificações nutricionais/produtos dietéticos, microorganismos/enzimas para alimentos, café/chá, produção de sacarose, novas plantas e frutos do mar. As patentes acadêmicas abrangem produtos de biodiversidade de alto valor nutricional, indicando possíveis especialidades futuras. Por outro lado, as

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tecnologias não acadêmicas giram principalmente em torno de produtos coloniais tradicionais exportados como commodities de baixo custo.

Palavras-chave: Alimentos. Fome. Avaliação de patentes. Níveis de prontidão tecnológica, Oportunidades tecnológicas para empresas. ODS2.

DESBLOQUEANDO EL POTENCIAL BRASILEÑO DE LAS TECNOLOGÍAS ALIMENTARIAS PARA ALCANZAR EL ODS 2 - HAMBRE CERO

Resumen

Brasil está trabajando para alcanzar el Objetivo de Desarrollo Sostenible 2 (ODS 2) de las Naciones Unidas, de Hambre Cero, pero volvió a aparecer en el mapa mundial del hambre en 2019-20. Este estudio busca identificar las tecnologías existentes en Brasil para abordar eficazmente los desafíos de la seguridad alimentaria. Se analizaron un total de 5.084 patentes de 45 campos tecnológicos alimentarios en la base de datos Worldwide Espacenet, utilizando la Clasificación Internacional de Patentes (CIP), que abarca desde 2000 hasta 2019. Las principales tecnologías incluyen productos de cacao, harina/masa, alimentos para animales, productos lácteos, productos preservados/madurados/enlatados, modificaciones nutricionales/productos dietéticos, microorganismos/enzimas para alimentos, café/té, producción de sacarosa, nuevas plantas y mariscos. Las patentes académicas incluyen productos de biodiversidad de alto valor nutricional, lo que indica posibles especialidades futuras. Por otro lado, las tecnologías no académicas se centran principalmente en productos coloniales tradicionales exportados como materias primas de bajo costo.

Palabras clave: Alimentos. Hambre. Evaluación de patentes. Niveles de preparación tecnológica. Oportunidades tecnológicas para empresas. ODS2.

1 INTRODUTION

The ongoing global challenge of addressing food security endures, representing a complex and multidimensional domain with profound implications for several of the United Nations' 17 Sustainable Development Goals (SDGs).

Within the broader framework of the 2030 Agenda, food security assumes a dual role as both a pivotal and constraining factor (SDO, 2015). Recent data provided by the Food and Agriculture Organization of the United Nations (FAO) underscores the pressing nature of this issue. Between 2019 and 2020, there was a notable increase in the prevalence of hunger, rising from 8.4% (720 million individuals) to 9.9% (811 million individuals). This increase represents a significant upturn, particularly within the context of Brazil (FAO, 2021a).

While Brazil has two primary national social protection programs, namely the cash-transfer Bolsa Família and the food-based Programa de Aquisição de Alimentos, which have been credited with helping Brazil exit the FAO's Hunger Map in 2014 (Mesquita; Bursztyn, 2016), it is regrettable that Brazil has reapeared on this map in recent times (FAO, 2021b).

Conversely, Brazil holds a prominent position as a global food producer, underscoring its indispensable role in the global food suply chain (FAO, 2021c). A significant portion of Brazil's export portfolio consists of various food products, encompassing a wide range of items such as soybeans, coffee, corn, cotton, diverse agricultural commodities, non-oil fruits and nuts, sugar and molasses, meat, and animal feed, among others (MCTI, 2021).

However, statistics from 2012 to 2019, derived from World Bank data, reveal that Brazil's share of high-technology exports as a percentage of total manufactured exports fluctuated modestly, ranging from 12% to 16% (WB, 2023).

Brazil, despite being in the uper-middle-income group and being one of the world's top food producers, as well as a leader in innovation within Latin America and the Caribbean, still maintains the 49th position in the Global Innovation Index 2023 rankings. This result does not reflect the country as a whole and is primarily attributed to the performance of a small region, specifically, its São Paulo science and technology cluster (Gii, 2023).

Food technologies, like all others, follow a scale of technological readiness levels (TRL), as a general rule. First, scientific research findings are typically reported in articles (TRL3), followed by the apropriation of initial technological developments through academic patents (TRL4). From this point onward, firms continue the technological development and file their non-academic patents (TRL5). Then, firms continue to improve the technologies until they reach the market (TRL9). Thus. patents serve as a relevant indicator of technological

development, serving as an early indicator of potential technological innovation (Nesta; Patel, 2004).

The phenomenon of patenting has experienced global proliferation, and Brazil is no exception to this trend, as it endeavors to establish a robust presence in the global high-technology market (WIPO, 2021). However, a preliminary search conducted by the authors within the European Patent Office's worldwide database (EPO, 2022), focusing on food technologies using IPC A23L and spanning the years 2000 to 2019, revealed that Brazil's contribution to this repository of patents amounted to just 0.5%.

In TRL3 bibliometric studies of food science related to sustainability, published articles revealed a Northern Hemisphere bias, predominance from developed countries, and a need for better integration with Brazil's relevant social, economic, and political dimensions (El Bilali et al., 2021).

For TRL5-9 in the Brazilian food industry, innovation is primarily concentrated in emerging enterprises or nascent industries, and there is a critical need for policy interventions to foster innovation ecosystems (Cabral, 1998; Cabral; Trail, 2008; Oliveira, 1998). A study by Costa et al. (2016) analyzed Brazilian food companies, revealing their low-tech attributes, limited academic R&D collaborations, and highlighting that, despite government suport, most sector advancements come from non-academic entities. A follow-up study by Capellesso et al. (2020) suported these findings, highlighting persistently low R&D investment, a prevailing low-tech status, and limited innovation realization within the food industry. Notably, the study identified an exception in sugar refining, which exhibited a high frequency of high-tech innovations.

For TRL4-5, a comprehensive examination of functional food innovation in Brazil, encompassing an analysis of patent activity within the Brazilian Institute of Industrial Property (INPI), reported high academic engagement, being the foremost contributor, with Brazilian residents accounting for nearly half of all patents filed (Hilachuk et al., 2021).

Brazil has national legislation governing academic patent regulation, technology transfer, and commercialization through the Innovation Act of 2004 (BR, 2004; Bacelar et al., 2021). Non-governmental associations like the National Forum of Innovation and Technology Transfer Managers – FORTEC, similar to counterparts in other nations, play pivotal roles in promoting patenting and facilitating technology transfer (FORTEC, 2022; Soares et al., 2020; Pires et al., 2017; Pires; Quintella, 2020).

In the present article, our primary focus centers on the identification of oportunities in the domain of food technologies that have the potential to contribute significantly to Brazil's

progress in achieving the targets stipulated in SDG2. The article deepens the assessment of available Brazilian food technologies as well as their aplicant organizations. A secondary aspect of our inquiry pertains to the examination of the extent to which academic and non-academic organizations are actively engaged in the development of technologies that hold relevance and promise for the nation, in order to diagnose potential routes to mitigate food insecurity in Brazil.

2 METHODS

This study assesses the Brazilian food technologies that could be used to combat hunger in the country, focused on TRL 4-5. Patents were maped using the International Classification (IPC) using WIPO Technology Domains and IPC Technology Concordance (Schmoch, 2008): 18 - Food Chemistry, 21 - Agriculture and Food Processing, and 14 - Agriculture, Food Chemistry. The A23L subclasses were also used for a more detailed analysis.

The patent search was conducted in February 2022, covering the 20-year period from 2000 to 2019, excluding the last two years due to the secrecy period. To prevent duplication resulting from multiple filings in different countries, FAMPAT patent families were utilized (FAMPAT, 2023).

The total number of patents considered only those filed by residents, using their earliest priority dates. Academic patents were identified by searching for each aplicant in the National Register of Higher Education Courses and Institutions for Brazil (E-MEC, 2017).

All patents were included for a comprehensive assessment of food technology oportunities. Patent data were sourced from the European Patent Office's global database (EPO, 2022) using Questel Orbit, chosen based on prior positive evaluations (Pires et al., 2020).

Data cleaning involved several steps: (1) excluding unrelated IPCs; (2) removing duplicates; (3) selecting the top 20 IPCs in each dataset; (4) excluding IPCs with minimal patent counts in at least two sectors; and (5) assigning 0.1 to years with zero patents in specific food fields (OECD, 2008). After cleaning the original 58 food IPCs, 45 food technology fields were retained, meeting established criteria by Van Zeebroeck et al. (2006): A01H, A01K, A01N, A01P, A21D, A23B, A23C, A23D, A23F, A23G, A23J, A23K, A23N, A23P, A47J, B01D, C07C, C07H, C07K, C08B, C12C, C12G, C12H, C12N, C12P, C13B, C13K, and A23L subclasses 2, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, and 35. The data analyzed consisted on 5,084 patents, being 1,814 from the academic sector, distributed in the 45 food fields (Table A of Suplementary material).

To unlock Brazil's potential in food technologies for SDG 2 – Zero Hunger, a comprehensive analysis was conducted for each field, considering the total number of patents,

the annual evolution of the patent's first priority year (for maturity and trends), and the percentage of top 10 aplicants' patents (for market monopoly tendencies). Additionally, data on family average size, countries where technologies were filed (for export intent evaluation), patent key themes (to infer predominant technologies), and top aplicants' technologies were collected.

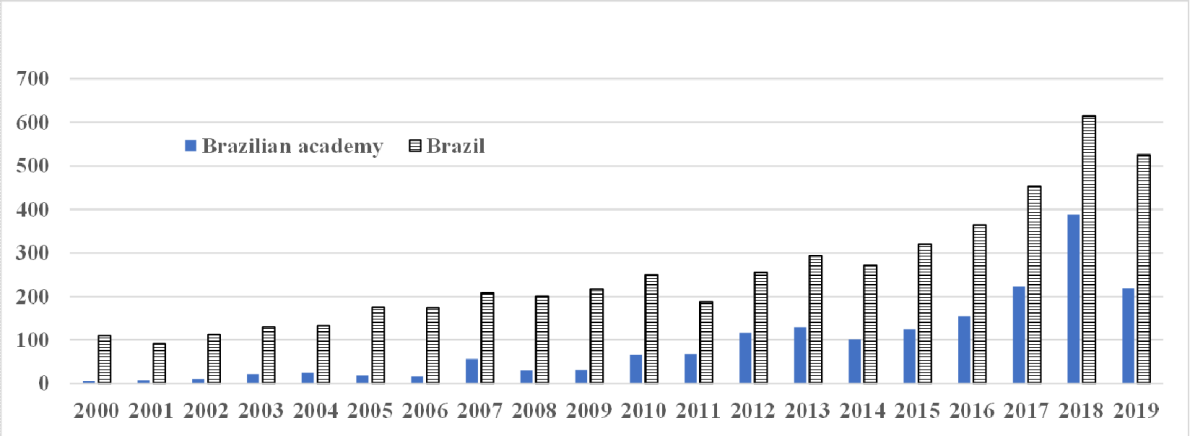
3 RESULTS AND DISCUSSION

The study outlines the temporal evolution of technologies in Brazil, including academic patents, top aplicants, and details on predominant food fields.

3.1 TEMPORAL EVOLUTION AND TOP ORGANIZATIONS

Fig. 1 displays the annual evolution of patented food technologies in Brazil, both for the country as a whole and its academic sector. Initially, it is observable that patenting is growing annually, although there apears to be a decline in 2019.

Figure 1. Annual evolution of Brazilian first priority data for food patents by Brazilian aplicants and by Brazilian academic aplicants.



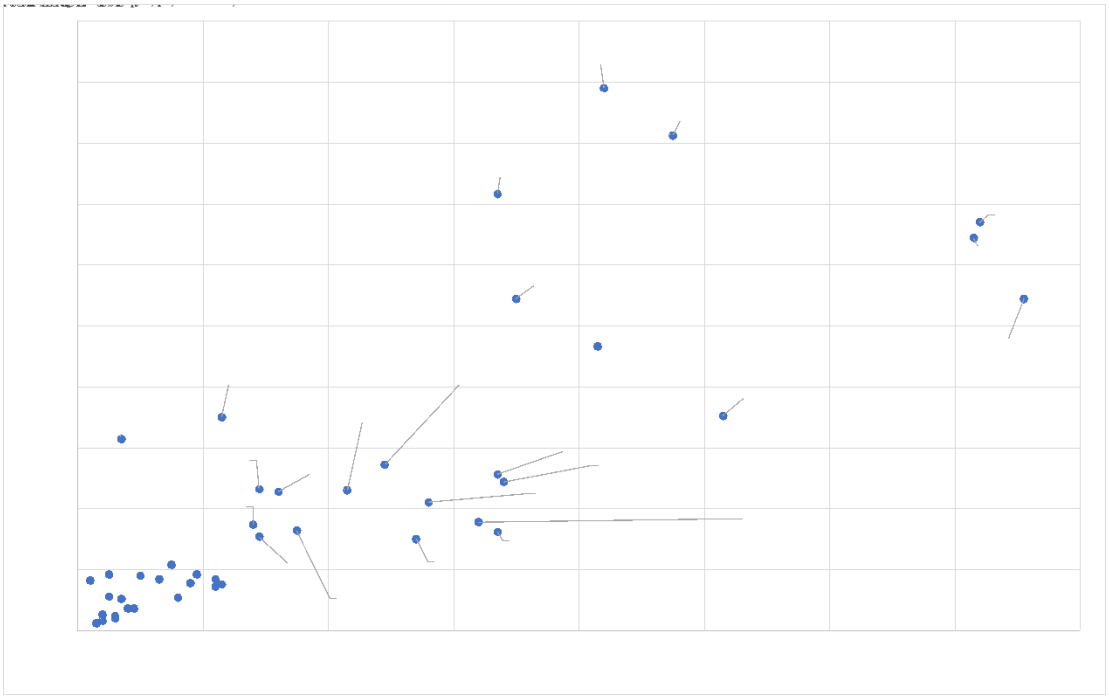
Source: Authors (2023).

It is noteworthy that the academic sector filled 36% of the patents, which is quite high, showing that Brazil is still too much in TRL4 and needs to increase non-academic patents (TRL5). In certain food fields it reaches more than 50% (Figure A of Suplementary material). Also, academic patents exhibited an annual increase since 2006, comprising more than half of the total patents filed in 2018. This may be a reflection of the Innovation Law stimulating patenting by academic organizations, especially considering that the academic sector governed by this law contributes aproximately 91.4% of academic patents.

Conversely, Brazil as a country does not exhibit a similar patenting growth rate, due to the lower rate of patenting by non-academic organizations. This atypical behavior, compared to other countries, highlights a bottleneck in food technology that is critical for achieving SDG2, and may be one of the contributing factors to Brazil's reemergence on the Hunger Map.

To further investigate, Fig. 2 displays academic patents versus total patents for each food field. The academic sector excels in high-tech fields, demanding advanced biotechnologies and profound scientific knowledge, including nutritional and dietary products, food preservation, dairy products, seafood, microorganisms or enzymes for food, and new plants. Non-academic organizations are more active in traditional colonial low-tech fields like cocoa and flour, as well as in a relevant field for meat producers, animal food.

Figure 2: Number of Brazilian academic patents versus Brazilian patents, highlighting the most relevant food fields.



Source: Authors (2023).

Here, oportunities exist for academia-firm partnerships to produce higher value-added goods, addressing food insecurity and generating tax revenue through markets with greater purchasing power, including exports.

Table 1 presents the top aplicants of food technologies. The academic sector occupies most of the top positions and is distributed across all regions of Brazil. Among the top non-academic organizations are the Brazilian Agricultural Research Corporation (EMBRAPA),

affiliated with the Ministry of Agriculture and Livestock; the National Service for Industrial Learning (SENAI); the National Institute for Amazonian Research (INPA); and the São Paulo State Research Suport Foundation (FAPESP).

Table 1: Brazilian top aplicants showing their number of food patents, organization type, Brazilian region.

Organization	Acronym	Type	Brazilian region	Patents
Federal University of Goiás	UFG	Academic	CO	14
Federal University of Mato Grosso do Sul	UFMS	Academic	CO	15
University of Brasília	UNB	Academic	DF	15
Federal University of Bahia	UFBA	Academic	NE	33
Federal University of Ceará	UFC	Academic	NE	56
Federal University of Campina Grande	UFCG	Academic	NE	104
Federal University of Paraiba	UFPB	Academic	NE	111
Federal University of Pernambuco	UFPE	Academic	NE	15
Federal Rural University of Pernambuco	UFRPE	Academic	NE	19
Federal University of Sergipe	UFS	Academic	NE	18
Federal Institute of Rondônia	IFRO	Academic	NO	13
Federal University of Roraima	IFRR	Academic	NO	47
Federal University of Amazonas	UFAM	Academic	NO	13
Federal University of Pará	UFPA	Academic	NO	17
Federal University of Roraima	UFRR	Academic	NO	35
Federal Institute of Rio de Janeiro	IFRJ	Academic	SE	15
Federal University of lavras	UFLA	Academic	SE	15
Federal University of Minas Gerais	UFMG	Academic	SE	15
Federal University of Rio de Janeiro	UFRJ	Academic	SE	18
Federal University of Viçosa	UFV	Academic	SE	34
Federal University of São Paulo	UNESP	Academic	SE	26
Campinas State University	UNICAMP	Academic	SE	83
São Paulo State University	USP	Academic	SE	55
State University of Londrina	UEL	Academic	SU	17
Federal University of Paraná	UFPR	Academic	SU	91
Brazilian Agricultural Research Corporation	EMBRAPA	Non-academic	DF	57
National Service for Industrial Learning	SENAI	Non-academic	DF	30
National Institute for Amazonian Research	INPA	Non-academic	NO	15
São Paulo State Research Support Foundation	FAPESP	Non-academic	SE	13

Source: Authors (2023).

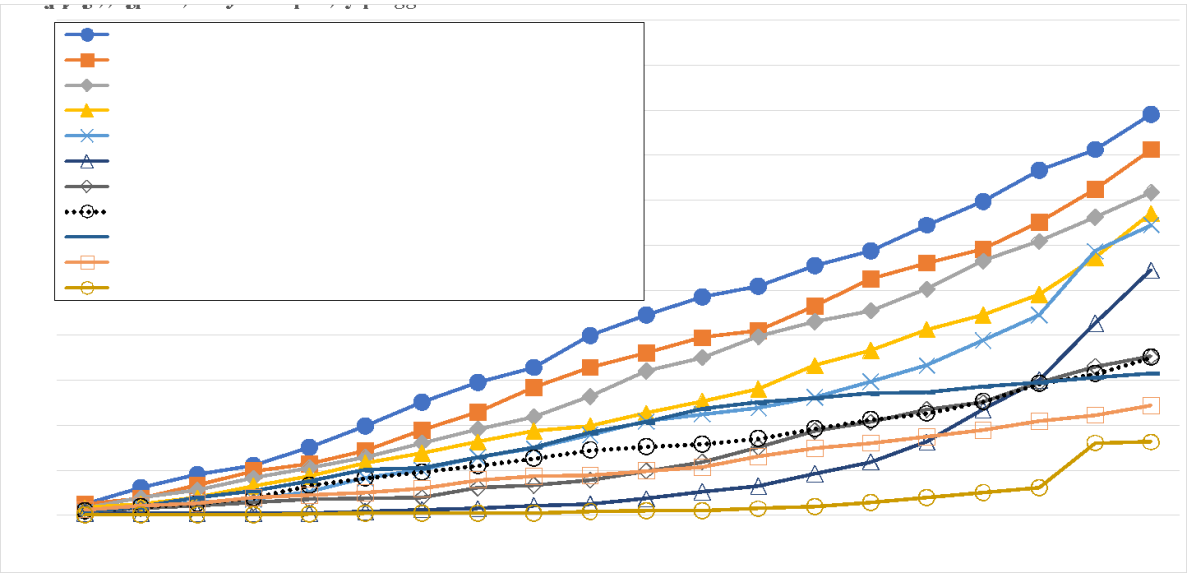
As mentioned earlier, nearly all of the academic aplicants belong to public institutions. It is evident that federal organizations lead in comparison to state organizations, in line with expectations, as federal funding follows a national resource distribution pattern, while state academia largely depends on local policies and funding. This provides an apropriate social framework for the implementation of national public policies aimed at SDG2, as part of a collaborative multi-organizational effort, led and financed by the federal government of Brazil.

3.2 FOOD TECHNOLOGICAL FIELDS

To identify oportunities related to SDG 2, the most relevant food technological fields were selected based on two criteria: having a significant contribution from academic patents or being a top food field in terms of production and exports.

Fig. 3 shows the cumulative time evolution of patents' first priority date for these relevant food fields: cocoa; cocoa products; flour or dough; animal food; dairy products; preserved, ripened, or canned products; nutritional modification and dietary products; microorganisms or enzymes for food; coffee, tea, and their substitutes; sucrose production; new plants; and food-from-the-sea, fish, fish meal, and fish-egg substitutes.

Figure 3: Accumulated time evolution of the Brazilian patents filled in the most relevant food technological fields.



Source: Authors (2023)

Almost all fields have been growing at a nearly steady rate, and in the last decade, there is a clear divergence due to increased growth in cocoa, flour, animal food, and dairy products, all of which are related to Brazil's top exports. The nutrition modifications and dietary products field is the exception; initially, it was not significant, but in the last decade, it has grown at an exponential rate. The field of food from the sea has started to grow in recent years and may become relevant in the future. The patent filings related to sucrose show a tendency to stagnate, possibly because this sector already has high TRL that does not require significant further technological developments.

All these food fields have the potential to contribute to achieving SDG2 and accelerating progress towards eradicating hunger, ultimately helping to move away from the Hunger Map. As a result, a comprehensive description follows, with a particular emphasis, when relevant, on academic technologies (TRL4) that hold the potential for further development into TRL5 by firms.

3.3 FOOD TECHNOLOGIES DESCRIPTION

a) Cocoa and cocoa products

Academic patents constituted only 19% of the total of 445. Between 2002 and 2019, patent aplications increased, reaching a peak of 13 in 2013 and continuing to rise in recent years. The top 10 aplicants hold 65% of these patents, indicating concentration, with an average family size of 1.1, primarily due to limited international protection. Leading institutions in this field are USP and UNICAMP.

The themes of academic patents include chocolate taste cream, crystal beta proportion, and cocoa butter replacer degrowth. USP's technologies focus on jackfruit seed cocoa substitutes and cupuaçu butter to reduce sucrose. UNICAMP concentrates on cocoa-derived products. The Federal University of Recôncavo Baiano (UFRB) has developed prebiotic beverages with bioactive compounds.

Non-academic patents only have 10% from the top 10 aplicants, indicating dispersion among them. The most relevant themes of non-academic patents include carob chocolate, polydextrose, composite coffee solid bar, and ice cream. The firm Gelita has filed 6 patents related to cocoa and fat-substitute protein technology.

b) Flour or dough

The patents retrieved were 406, with 23% originating from the academic sector.

For academic patents, there was consistent annual growth in the number of patent aplications, especially between 2013 and 2018, increasing from 7 to 20 aplications. The average family size 1.2 suggests that technology protection is primarily for Brazil's consumption. Prominent themes include chocolate taste cream, trans fatty acid, castor sunflower, low-calorie product manufacture, and diagnostic reactive material.

The top 10 academic aplicants account for 68% of the total aplications, indicating a concentration within aplicants. The two top aplicants are the UFCG and UFC, with 16 and 15 patents, respectively.

UFCG's technologies primarily focus on the development of new products for human consumption containing microalgae, typical regional vegetables, and those sourced from family agriculture (such as pumpkins, cassava, umbu, mandacaru, moringa, bananas, red rice, peanuts, etc.). These products exhibit enhanced nutritional value when compared to conventional foods. Additionally, there is also emphasis on process development, exemplified by the technology Convective Drying of Osmotically Dehydrated Cassava Cubes (BR102019014072).

UFC's technologies also center around the development of new products and processes with a focus on utilizing fishery products. For instance, Savory Biscuit with the Addition of

Fish Protein Concentrate and the Corresponding Production Process (BRPI1005511). Other technologies concentrate on the development of functional foods, predominantly of plant origin.

Regarding patents filed by non-academic organizations, the top 10 aplicants represent only 6% of the total aplications, indicating dispersion among aplicants. Over the 20-year period, a slight increase in non-academic patents is observed in 2019, amounting to 33 patents.

The company Sabor & Cia Confeitaria contributed with 6 patents, all related to the manufacturing and preparation process of the final product, namely, pies. The second company, Granotec, filled 5 patents referring to the manufacturing process and bakery products, including bread, yeast, and soy flour enriched with enzymes (BRPI0701130) synergistically enhancing the wheat flour fermentation process.

c) Animals food, feeding-stuffs specially adapted for animals

There were 358 patents, with only 19% originating from the academic sector. Patents increased from 2 in 2002 to 22 in 2019. The average family size is 2.6, suggesting active protection of inventions in multiple territories with a focus on exports to Europe and the USA. The top 10 aplicants represent 12% of total aplications, indicating significant diversity among aplicants. Prominent themes include bicalcium phosphate, cattle, additive feed, ruminant, sorghum grain, and diverse wort. TS Suplementacao Animal leads, and Yessinergy Holding are the top aplicants.

TS Suplementacao Animal focuses on developing compositions and products for animal nutritional suplementation, encompassing equines (Equine nutrient composition BR102016029444 A0), dogs (Dog nutrient composition BR102016029446 A0), and cats (Body improvement nutrient composition for cats BR102016029453).

Yessinergy Holding also focuses on animal nutrition, with inventions like Immunomodulating and growth-promoting composition controlling undesirable bacteria in the intestinal microbiota (WO2017/219106) and Composition of growth-promoting prebiotic additives for animal feedstuffs (WO2019/046919). They also work on processes and products for animal feeds, nutraceuticals, and food suplements, such as Process for increased concentration and activity of mannans and beta-glucans in Saccharomyces cerevisiae-derived products (BR102015032395).

d) Dairy products

There were 355 patents retrieved, with 43% originating from the academic sector. The average family size in the academic sector is 1.1, indicating that the intent for exports is nearly absent. From 2002 to 2019, patent aplications grew steadily, with a peak of 30 in 2018. The top 10 academic aplicants own 64% of the patents, demonstrating concentration. The top aplicants

are Federal Universities in the Brazilian Northeast Region, with UFPB leading (28), UFCG (17), and UFC (9). Key themes in the academic sector include aromatized dessert products, diagnostic reagent materials, and Bifidobacterium animal ssp. UFPB focuses on probiotic ingredients and dairy products, while UFCG specializes in dairy products and collaborations. UFC develops functional foods and beverages, such as the Process of making probiotic nectar and nectar obtained.

For non-academic patents, the top 10 aplicants own 18%, indicating an absence of a monopoly. Only 32% are currently active. In 2019, there was a significant increase to 28 patents. Themes include home yogurt manufacture, inventor eye, bovine triol, and fluid dairy hotspot.

The leading non-academic aplicants are SENAI and INPA, both focusing on beverages, desserts, and dairy formulations with functional ingredients, such as Processing of xylooligosaccharide-added dairy beverage.

Gervais Danone has industrial technologies for fermented dairy products.

e) Preserved and ripened or canned products

The patents retrieved numbered 322, with 44% originating from the academic sector. From 2002 to 2019, there was no consistent growth rate, but a substantial inflection point occurred in 2018, transitioning from an average of 1 patent aplication per year to 59 in 2018. The average family size of 1 suggests no intent for exports. The top 10 aplicants hold 68% of the total aplications, indicating a concentration among them.

Federal University of Rondônia (UNIR) (34) and IFRO (33) stand out in terms of the number of patents, a result of collaborative R&D. Prominent themes include beta-gurjunene (aromadendrane sesquiterpenoids), bulk aluminum packaging, among other.

f) Nutritional modification and dietary products

There were 272 patents retrieved, with 55% originating from the academic sector. Family average size is nearly one. The top 10 aplicants hold 59% of the aplications. Aplications experienced growth from 2002 to 2019, with significant growth observed from 2010 onwards. Prominent themes include chocolate taste cream, sequence peptide alternative, and defatted passion fruit bagasse.

Federal Universities in the Northeast Region of Brazil, such as UFPB (21), UFCG (20), and UFC (11), excel in diverse technologies focusing on new food products and processes, often incorporating regional ingredients into health-promoting foods. Examples include Yam flour enriched probiotic plant beverage (BR102018006778) and High fiber pepermint pineaple jelly from waste pineaple juice industry (BR102019023998).

UFCG similarly develops technologies for new food products, often utilizing regional, cost-effective raw materials, like Aloe vera pulp (aloe vera p.) powder (BR102019005268). They also enrich products with microalgae, e.g., Process for preparing fresh, noodle-like food dough, enriched in microalgae spirulina platensis (BR102018015732), and dietary needs like Badella-type sausage made from mechanically separated meat (CMS) of freshwater fish with inulin addition (BR102018009840).

UFC follows a similar trend, developing products and processes that involve regional fruits, like Obtaining a smoothie tropical fruit drink prepared with water-soluble extract of cashew nut almond (BR102018007898). They also focus on dietary restrictions, such as Process of making probiotic nectar and nectar obtained (BR102015030454), and bioactive-rich products, like Bioactive compound of yacon syrup and carotenoid extract (BR102018007265 A0), developed in collaboration with EMBRAPA.

g) Microorganisms or enzymes for food

In the food field of Microorganisms or enzymes for food, Brazil had 176 patents, with 58% originating from the academic sector. From 2002 to 2019, patents increased, with significant growth in the last decade. The top 10 aplicants control 64%, showing substantive concentration. The average family size (1.4) indicates low intention for exports. The top aplicants are EMBRAPA, UNICAMP, and UNESP.

The main themes encompass pest and genetically modified plant production. EMBRAPA develops technologies for agricultural production and plant products, enhancing pest resistance and gene expression supression efficiency. UNICAMP, as a co-aplicant with EMBRAPA, explores biotechnologies for food production, including microbial protease use in cheese-making. UNESP, also a co-aplicant with EMBRAPA, focuses on plant-related technologies and biotechnology for food, emphasizing nutritional enrichment.

h) Coffee; tea; their substitutes

There were 175 patents, with only 13% originating from the academic sector. The number of patents increased slightly from 2002 to 2019, peaking at 17 in 2017. The average family size is 2.3, indicating an intention for exports, particularly to Europe and the USA. The top 10 aplicants account for 13% of total aplications, reflecting significant dispersion among them. Key themes include population antioxidant diet, herb infusion, coffee regulated passage, coffee concentrate, big ripe cherry, and vegetal origin reconstruction powder.

Industry Mate Laranjeiras and Regional Cafeicultores em Guaxupe Cooxupe Coop hold 3 patents. They develop technologies for the coffee industry, such as Productive process for deodorizing green coffee oil (BR102014026042), Production system for extracting, treating,

and potting arabica coffee oil (BR102014025970), and Productive process for obtaining green coffee oil (BR102014026029). Their focus extends to green matte tea, with inventions like Process of making green or roasted matte tea powder and its products obtained (BRPI0901220 B1), and yerba mate, including Process of obtaining and resulting organic, green or roasted, gasified yerba mate beverage product (BRPI0802975) and Carbonated yerba mate beverage and its process of manufacture (BR102015021004).

The Coca-Cola Company also has one protected technology in this category: Process for the manufacture of extract from dry guarana seeds (WO2006/032119) with priority in Brazil.

i) Sucrose production

A total of 157 patents were retrieved, being only 4.5% from the academy. These patents were filed across all five continents, although with a relatively small average family size of 1.5. From 2002 to 2019, there was no consistent growth rate, with increases in the number of deposits in 2009 (17) and 2011 (15). Notably, 77% of the patent aplications have a dead status, meaning they are no longer enforceable due to having expired and can be freely used by anyone.

The top 10 aplicants hold only 22% of the total aplications, indicating a high dispersion with no monopoly elements. Prominent themes include filtrated syrup, juice clarification, bagasse submission, bagasse cleaner, crystallization seed, dry powder sugarcane juice, and acid tolerance mesophyllum microorganisms.

Key aplicants include Maqtron Imports and Exports (6), Sermatec Industry & Assembly (6), and Dedini Base Industry (5). Maqtron Imports and Exports focuses on developing mechanisms and equipment for industrial sucrose manufacturing, including improvements aplied to sugarcane milling mechanisms and other related technologies. Sermatec Industry & Assembly specializes in systems, devices, and aparatus related to industrial sucrose manufacturing, with notable contributions in cleaning systems, chain adjustment devices, and distribution systems for diffusers used in the sugarcane industry. Dedini Base Industry develops technologies primarily related to the sucrose production process, including processes for producing liquid sugar, equipment for dry cleaning of sugarcane, and sugar crystallization processes.

j) New plants

The patents numbered 122, with 56% originating from the academic sector. The top 10 aplicants hold 60% of the total aplications, indicating a concentration among them. From 2002 to 2019, there was relatively steady growth, with peaks in 2012 (10) and 2017 (10). The average family size is 1.6, with a minor intent of exportation, primarily limited to the Brazilian territory.

The largest aplicant is EMBRAPA (22), collaborating with universities (e.g., UNB, UFG, UNESP). Examples include Method and Compositions for Controlling Pest Insects on Plants by Silencing Genes of the Chitin Synthase and of the Vitellogenin Family, as well as Alternatively by Expressing the Gene of a Cry Toxin (WO2015/089616).

k) Food-from-the-sea, fish, fish meal, and fish-egg substitutes

A total of 81 patents were retrieved, with 85% originating from the academic sector. These patents were exclusively filed in Brazil. From 2002 to 2019, there was no consistent growth rate, but a notable inflection point occurred in 2018, where the number of patent aplications increased significantly, rising from an average of 1 patent aplication per year to 48 in 2018. The top 10 aplicants hold 91% of the total aplications, with a significant concentration in federal universities and institutes in the Northern Region of Brazil.

UNIR and IFRO stand out, jointly holding over 67% of the total patents due to collaborative R&D. Their technologies refer to the production of food products for human consumption, primarily based on indigenous fish species such as Jatuarana (brycon sp.), Tambaqui, Pirarucu, Pintado. These products include edible oil, pâté, meatballs, etc., exemplified by technologies like Creamy and Pastier Pâté Production Process, Smoked or Unsmoked, Based on Freshwater Fish (BR102018001138), Meatballs with Pintado in Tomato Sauce with Flaxseed (BR102018001102), Pirarucu in Edible Oil (BR102018001314), and Jatuarana (brycon sp.) in Tomato Sauce with Smoked Peper Flavor (BR102018001127).

4 FINAL CONSIDERATIONS

This study maped Brazilian food technologies and analyzed country patents. Its aim was to identify and disseminate potential processes and products that could be incorporated into firms' strategies to achieve SDG 2 and reduce food insecurity in Brazil.

Brazilian academic patents (TRL4) typically encompass high-value-added technologies that are grounded in the country's abundant biodiversity. These technologies encompass a wide range of fields, including dairy products, nutritional modifications and dietary products, preserved, ripened, or canned products. Additionally, there has been a significant and recent contribution in the field of food-from-the-sea, covering fish, fish meal, and fish-egg substitutes.

Academic technologies also play a significant role in high-tech food biotechnology fields such as microorganisms or enzymes for food and new plants. These academic technologies have the potential to address health disorders resulting from inadequate nutrition. Furthermore, when in partnerships with firms, they can be commercialized as specialty products, potentially generating a high financial return.

Non-academic patents (TRL5), on the other hand, primarily concentrate on enhancing traditional Brazilian colonial-era technologies, such as cocoa and cocoa products, flour or dough, coffee, tea, their substitutes, and sucrose production. They also prioritize animal food and feeding-stuffs specifically adapted for animals. Most of these technologies result in products that are exported as commodities at low international prices, similar to other former colonies that also produce them. Only two technologies have an explicit focus on exports: animal food and coffee and its products.

An oportunity that has yet to be fully explored by Brazilian firms is active involvement in the development of new food technologies based on the nutritive value of the country's biodiversity. New regulations are needed, but the government should be careful, as they may either promote or hinder academic and non-academic strategies related to property rights, as previously studied in Norway (Grimsby; Gulbrandsen, 2022).

The utilization of these oportunities to address SDG2 will also depend on firms' post-COVID-19 pandemic efforts to re-strategize, reshape, and redesign themselves in a smarter and more resilient manner, adapting to changes in the global food suply chains (Alabi; Ngwenyama, 2023). Additionally, it will depend on the pattern of patent filing, which has varied widely across technological domains and world regions (Fink et al., 2022).

Another critical parameter is the necessity for firms to incorporate sustainability into their strategies. This incorporation can reinforce the development of high-impact food technology and, consequently, contribute to the achievement of several goals outlined in the 2030 Agenda, including SDG 2. This trend is already being observed in Brazil (Matzembacher; Meira, 2019).

Will the already successful Brazilian national programs Bolsa Família and Programa de Aquisição de Alimentos (Mesquita; Bursztyn, 2016) be complemented by a new national program in Brazil to foster partnerships between academia and non-academic organizations for food technological development?

Another significant challenge is the interconnected balance between food, energy, and water (Zhu et al., 2020). Will new mixed production chains, which utilize raw materials, excess production, and recycling of products and byproducts, consider these critical constraints to achieve SDG 2 and meet the aims of Agenda 2030?

Additionally, network companies are already operating in the Pampa region of southern Brazil (Clasadonte et al., 2013). Will this business model, which mitigates risks related to climatic changes, soil-crop combinations, and market fluctuations, present an oportunity to share surplus food production? Will the Brazilian government regulate it to align with SDG2,

or will these companies evolve into an oligopolistic agri-food market enterprise, without addressing the urgent need for local social programs to achieve the SDG of zero hunger?

This article has highlighted several oportunities that can be explored by lean companies with adaptable business models. These oportunities align with current trends such as smart farming (Musa; Basir, 2021), startups (Matricano et al., 2022), and short food suply chains (Luo et al., 2022).

The oportunities identified by this article are immense and can be leveraged for the development of affordable local technologies to combat hunger on Our Home, planet Earth. In the coming years, we will observe whether companies have integrated these oportunities into their portfolios and contributed to the achievement of SDG2!

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Unlocking the Brazilian potential of food technologies to attain SDG 2 – Zero hunger

SUPLEMENTARY MATERIAL

TABLE

Table A: Total patent numbers of each food technological fields from 2000 to 2019 for each food field, with its International Patent Classification (IPC): Brazilian academic patents; Brazilian patents.

Technologic field	IPC	Academic patents	Total patents
Alcoholic beverages (processing)	C12H	15	54
Animal breeding	A01K	4	13
Animal's food - feeding-stuffs specially adapted for animals	A23K	67	358
Brewing	C12C	29	77
Cereal-derived and malt products	A23L-007	56	105
Cocoa; cocoa products	A23G	84	445
Coffee; tea; their substitutes	A23F	23	175
Compositions of proteins and phosphates	A23J	49	136
Containing additives	A23L-029	64	89
Dairy products	A23C	144	335
Edible oils or fats	A23D	28	87
Egg products	A23L-015	3	6
Fermentation and enzymatic processes	C12P	43	115
Flavors, feed composition, insecticides, antifungals, etc.	C07C	5	28
Flour or dough	A21D	95	406
Food shapes	A23P	32	114
Food-from-the-sea, fish, fish meal, fish-egg substitutes	A23L-017	67	81
Fruit and vegetable processing machines	A23N	5	46
Fungi (edible)	A23L-031	6	10
Improvements in feeding with peptides	C07K	23	38
Kitchen equipment	A47J	2	41
Leguminous	A23L-011	8	18
Food mainly of nutmeat or seeds	A23L-025	16	27
Marmalades, jams, jellies, products from apiculture	A23L-021	54	75
Meat products	A23L-013	19	46
Microorganisms or enzymes for food	C12N	103	176
New plants	A01H	68	122
Non-alcoholic beverages, dry compositions or concentrates	A23L-002	70	272
Nutritional modification and dietary products	A23L-033	151	272
Others	A23L-035	6	11
Plant improvements	A01P	9	18
Polysaccharides	C08B	18	39
Preparation or treatment	A23L-005	22	36
Preservation	A23L-003	83	233
Preservation of animal parts	A01N	22	42
Preserved, ripened or canned products	A23B	143	322
Products from fruits or vegetables	A23L-019	67	128

Table A: Total patent numbers of each food technological fields from 2000 to 2019 for each food field, with its International Patent Classification (IPC): Brazilian academic patents; Brazilian patents.

Technologic field	IPC	Academic patents	Total patents
Puddings and creams' substitutes	A23L-009	4	8
Saccharides (except sucrose)	C13K	10	45
Separation - physical or chemical processes or apparatus in general	B01D	13	42
Soups and sauces	A23L-023	6	12
Spices, flavoring agents or condiments, artificial sweetening agents, table salts; dietetic salt substitutes	A23L-027	35	82
Sucrose production	C13B	7	157
Sugar and nuclear products and their deliveries	C07H	7	26
Wine and other alcoholic beverages	C12G	29	116
TOTAL	-	1,814	5,084

Unlocking the Brazilian potential of food technologies to attain SDG 2 – Zero hunger

SUPLEMENTARY MATERIAL

FIGURE

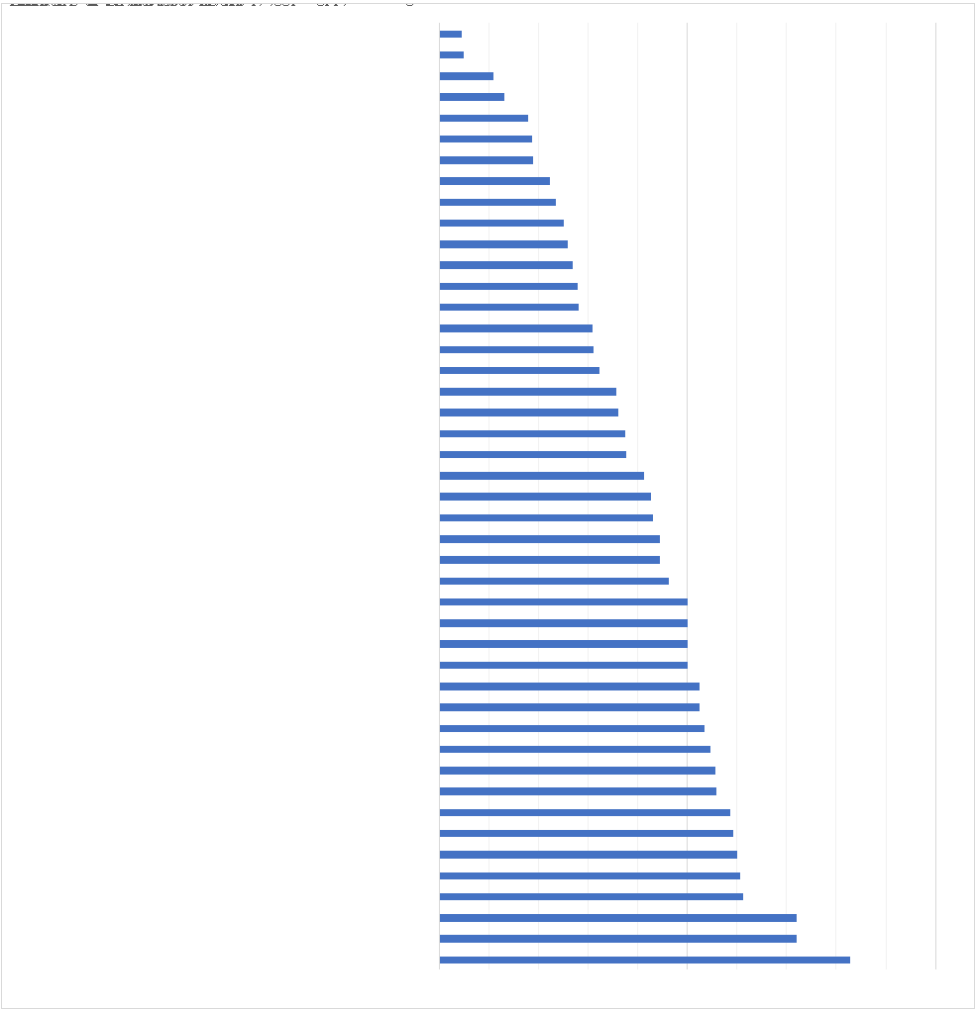

Figure A: Percentage of Brazilian academic patents within each food field.

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