



NANOTECHNOLOGIES RELEVANT TO THE FOOD AND BEVERAGE INDUSTRY: ANALYSIS OF INTELLECTUAL PROPERTY AND TECHNOLOGY TRANSFER IN THE GLOBAL AND BRAZILIAN CONTEXT

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Abstract: This study aims to map intellectual property and technology transfer related to nanotechnologies of greatest relevance to industries in general and the food and beverage sector, both globally and in Brazil. The classification of this study is exploratory, descriptive, and documentary, using patentometrics with the support of Orbit Intelligence software. The results between 2015 and 2024 show that nanomaterials grew by 137.02%, nanoparticles grew by 61.58%; nanoemulsions grew by 170.91%; and nanocapsules had a 60.58% reduction in protections compared to the first five years (2015 and 2019). Patents in “food/food products/beverages” between 2015 and 2024 point to a 171.08% growth in nanoemulsions; a 72.73% reduction in nanocapsule protections; a 136.83% increase in nanoparticles; and a 184.83% increase in nanomaterials. Nanotechnology drives sustainability and aligns with the UN's Sustainable Development Goals (SDGs). In Brazil, nanotechnological development leverages biodiversity for applications in the bioeconomy and industry, using active ingredients in various forms. However, the adoption of this disruptive technology by Brazilian industries is limited. This highlights the urgent need for effective public policies to foster its advancement in the country.

Keywords—Industry, nanotechnology, disruptive, innovation

1 INTRODUCTION

Nanotechnology is part of the concept of Industry 4.0, i.e., the fourth industrial revolution (Bai *et al.*, 2020) and has become a major advance with immense potential for promoting sustainability (Sridhar *et al.*, 2021). In Brazil, expectations for industry innovation by 2027 include the development of five areas: (I) Nanomedicine and Nanocosmetics; (II) Flexible and wearable clothing and devices; (III) Sensing for the Internet of Things (IoT); (IV) Nanotechnology for Energy; and (V) Nanotechnology for Food (IEL, 2018).

Nanotechnology is considered a convergent and enabling technology, according to SETEC/MCTIC (2016), due to its ability to cause radical technological changes that transform humanity and its culture, which is why it is cross-cutting and disruptive. It has the potential to generate rapid cycles of innovation but also requires high investment and specialized human capital (MCTI, Brazil, 2021).



According to Onyeaka *et al.* (2022), nanotechnology involves the development, characterization, and application of structures ranging in size from 1 to 100 nm. According to PINTEC 2011, nanotechnology can manipulate atoms and molecules on a nanometric scale, that is, one billionth of a meter (1 nm = 10⁻⁹m). It has been called nanoscale technology because it produces nanostructured materials with new properties and purposes (Chadha *et al.*, 2022).

Sekhon (2014) pointed to agri-food nanotechnology as a driving force for the near future, attributing to it the ability to solve many critical problems for the global food supply. Rashidi and Darani (2011) explored nanotechnology in the food industry for pathogen detection, disease treatment delivery systems, food packaging, and targeted delivery of bioactive compounds. In 2018, this technology contributes to food safety and “nanofoods,” food traceability, sensors for precision agriculture, and food processing (IEL, 2018).

According to Sahoo *et al.*, 2021, nanotechnology applications have two main activities in the food industry: (i) food processing and preservation and (ii) packaging. According to the Brazilian Soft Drink Manufacturers Association (Afebras, 2024), nanotechnology impacts all stages of the beverage production process, from manufacturing to processing, transportation, packaging, bioavailability, and shelf life.

Singh and Packirisamy (2022) advocate the use of naturally processed nanotechnology-based products, such as nanonutraceuticals, nanofoods, nanofertilizers, and nanopesticides for the benefit of human health. In the beverage industry, fruits and their by-products are transformed via nanotechnology into fermented beverages with high added value, becoming functional foods (Rodrigues *et al.*, 2021).

It is also worth noting the negative aspects and technological gaps related to nanotechnology and food safety and the environment. Sahoo *et al.* (2021) highlights that its application has attracted the attention of policymakers, conscious consumers, international regulatory agencies, and various other stakeholders. Some studies point to health risks in high doses of polyphenols in smart packaging (Milincic *et al.*, 2019), and the toxicity of nanoparticles and nanomaterials is not well understood (Onyeaka *et al.* 2022) such as potent nanocomponents, so that some nanosystems are still in the early stages or under development (Sahoo *et al.*, 2021; Chadha, *et al.*, 2022), among others.

Nanosafety emerged to assess the safety of nanomaterials and nanoproducts in the value chain, for greater legal and health security, environmental sustainability, with a view to economic growth and the promotion of social justice (MCTI, Brazil, 2025). According to Teunenbroek, Baker, and Dijkzeul (2017), uncertainty about the effects, risks, and methods to be tested, in the context of current regulations, is preventing the full exploitation of the innovative potential of nanomaterials. An international regulatory initiative, the NANOReG projects (A common European approach to the regulatory testing of Manufactured Nanomaterials), according to Dekkers *et al.* (2016), aimed to develop, in the long term, new testing strategies adapted to many nanomaterials where many factors can cause environmental and health impacts.

This study aims to map intellectual property and technology transfer related to nanotechnologies of greatest relevance to industries, particularly the food and beverage industries, both globally and in Brazil.

2 METHOD

The classification of this study is exploratory, descriptive, and documentary, as it is necessary to explore the information to identify relevant variables on the topic to construct an in-depth analysis. It

is descriptive to detail the characteristics of the level of nanotechnologies and existing practices in the food and beverage industry scenario worldwide and in Brazil, as well as documentary, as the research uses legal and strategic documents on these industries.

The research techniques and data sources are based on documentary research on the industry selected for the study. The use of patentometrics for technological mapping, patent searches, and data processing using Questel's Orbit Intelligence System, which accesses the international database (Worldwide) administered by the European Patent Office (EPO/EPA/IEP). And the analysis of secondary public data from the National Innovation Survey (PINTEC).

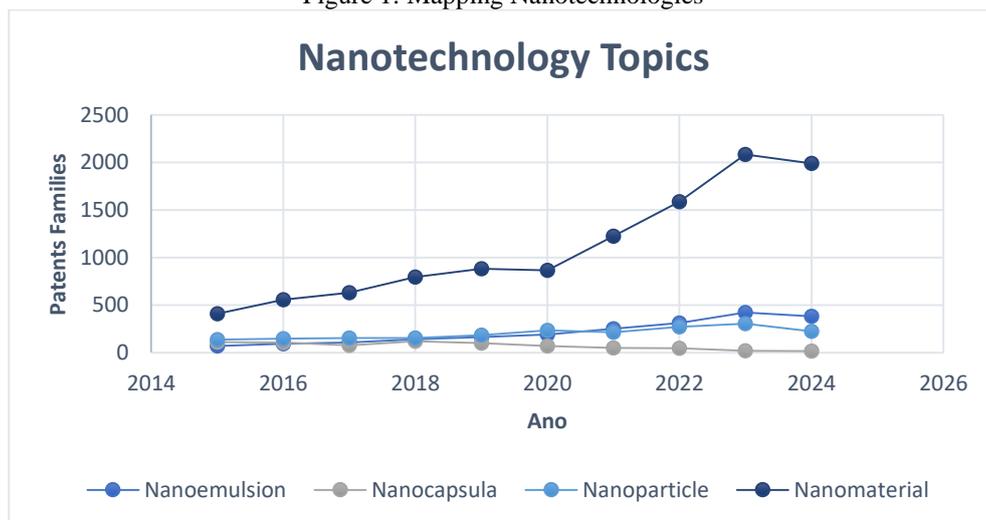
The approach is quantitative, using quantitative data from patentometrics as well as statistics from PINTEC.

3 DISCUSSION AND RESULTS

Scientific mapping on nanotechnology has indicated some thematic trends from 2020 onwards, such as nanoemulsions, encapsulation, nanoparticles/silver nanoparticles, and nanomaterials for observing the production chain. In terms of the number of scientific publications on nanoparticles, nanoemulsions, and nanomaterials, China, the United States, and India occupy the top three spots in the ranking. Regarding nanocapsules, Brazil ranks third, after China and the United States.

Over the last ten years, from 2015 to 2024, the number of patents/patent families was compared to measure the percentage variation in each technological area in terms of advances or lack thereof. The volume of nanomaterial technologies was more significant in this period, with a growth of 137.02% in comparison with the last five years (2020 to 2024). Nanoparticles grew by 61.58%; nanoemulsions grew by 170.91%; and nanocapsules saw a 60.58% reduction in protections compared to the first five years (2015 to 2019). This can be attributed to the stagnation of technological advances in nanocapsules, based on the state of the art.

Figure 1: Mapping Nanotechnologies

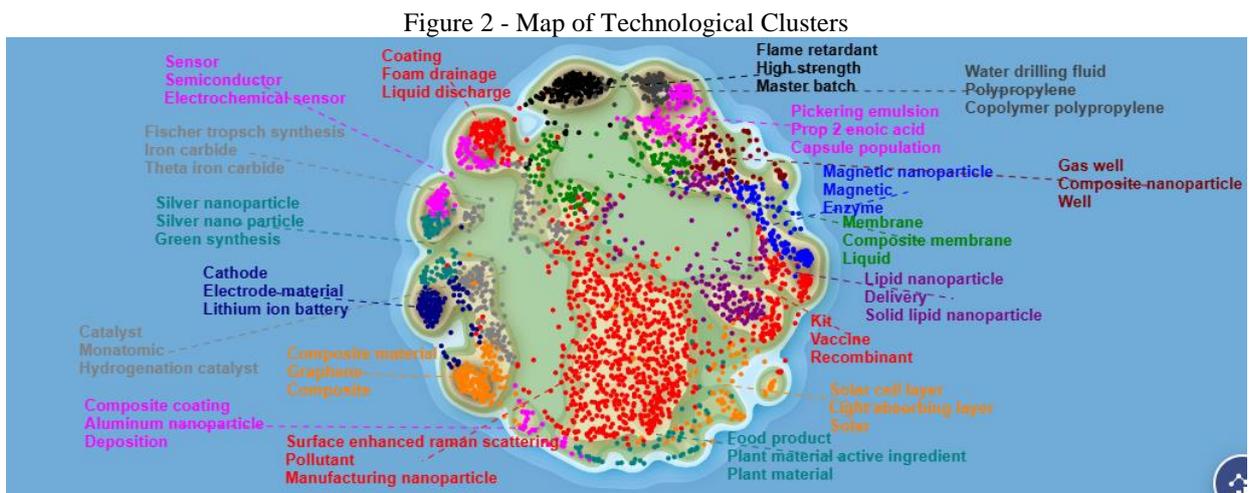


Source: Prepared by the authors (2025).

The number of nanoemulsion protections peaked at 421 patents in 2023; nanocapsules peaked at 119 patents in 2018; nanoparticles peaked at 304 in 2023; and nanomaterials peaked at 2,084 patents in 2023.

Data on technology licensing on the Orbit Intelligence reporting platform indicates that companies developing nanotechnology encounter difficulties in transferring technology in the global context. Considering the number of licenses for nanoemulsion (1), nanocapsule (1), nanoparticle (95), and nanomaterial (5), nanoparticles achieve a much higher number than other technologies, given their greater added value and specificity for industrial use. The nanotechnology licensing rate, considering the total number of licenses and the total number of guaranteed and pending technologies, is as follows: nanoemulsion (0.04%), nanocapsule (0.08%), nanoparticle (0.10%), and nanomaterial (0.04%).

Figure 2, a map of technological clusters based on nanoparticle patent data, shows the range of applications in health, the environment, energy, manufacturing, and oil and gas. They are responsible for the application of sensors, semiconductors, and electrochemical sensors; carbide synthesis and catalysis; nanoparticles and green synthesis; lithium-ion batteries; coatings; SERS and pollutants; industrial coatings; drainage and discharge of liquids; flame retardants and high-strength materials, emulsions and encapsulation, magnetic nanoparticles and enzymes; composite membranes; lipid nanoparticles; vaccines and recombinants, solar cells; food products and plant materials; drilling fluids and polymers; and gas wells and composite nanoparticles. The densest clusters indicate degree of maturity and technological intensity, such as batteries, sensors, and vaccines/LNP, which have large volumes of patents.



Source: Prepared by the authors (2025).

It is worth noting that, in terms of the development of silver nanoparticles, Xerox is the strongest player in the market, with 42 patent families. Over the last ten years, the patent with the greatest impact has been the Intercalary Printing Process (EP3355668), due to the highest number of citations and geographical coverage. It should be noted that nanoparticle inks play a vital role in the integration of electronic devices, according to their authors Naveen et al. (2017).

Nanotechnologies protected in Brazil indicate a good consumer market, due to the protection of patent families originating in other countries. The total number of patents granted, and pending are shown in Table 1, by broad technical and technological field and applications, and those related to “food/foodstuff/beverage”.

In the food/foodstuff/beverage area of nanoparticles, three companies stand out: Irish companies Elan Pharma International, Alkermes Pharma, and BASF. Swiss company Firmenich for



nanoemulsions; Israeli startup Melodea in nanomaterials; and Spanish company LIPOTEC, acquired by Lubrizol/Lipoffods.

In the context of nanotechnologies for food products and processes, such as the food and beverage manufacturing industries, the contributions are less significant, so we will highlight some technologies from each segment. Based on the mapping of nanoemulsion technologies, their applications in the beverage industry, which may contain products with natural pigment ingredients, such as carotenoids, antioxidants, surfactants, aqueous solutions, nanoparticles, and homogenization and emulsification processes. For example, patent No. EP3379941 - Nanoemulsions for beverages produced by high shear processing, from PEPSICO, protected in 2015 in countries including Brazil. Composition and method for manufacturing clear beverages comprising nanoemulsions with quillaja saponins - EP2013055113.

Table 1 – Mapping of Patent Families in the period from 2015 to 2024

<i>Nanotechnologies</i>	<i>Global</i>	<i>food/foodstuff/beverage</i>
Nanoemulsion	278	25
Nanocapsules	58	09
Nanoparticle	2117	122
Nanomaterial	178	12

Source: Prepared by the authors (2025).

Nanoemulsions have various applications in functional food products and supplements, in addition to their use in the pharmaceutical industry, among others. It is worth highlighting the patent granted - BR 11 2020 003962 4 - Method for obtaining a nanoemulsion with encapsulated natural antioxidants for the preservation of fresh and minimally processed foods, and the nanoemulsion thus obtained. In addition, there is a green patent for the use of waste from the manufacture of beverages and foods.

Table 2 - Green Nanoemulsion Technology

Green Technology	Assignie	Year
Development of pickering nanoemulsion of chitin nanofibers with bioactive extract from hop residues - BR 10 2024 002803 1	Federal University of Rio Grande (FURG).	2024

Source: Prepared by the authors (2025).

As for encapsulation technology, Compositions based on propolis nanocapsules which can be used as carriers for substances of interest, methods for producing same and use thereof (EP2633862) by the Brazilian Agricultural Research Corporation (EMBRAPA) protected its technology in the world's largest markets, the United States and China.

Other nanotechnologies focused on encapsulation, nanoparticles, and nanomaterials applied to the food industry are shown in Table 3.

Table 3 - Encapsulation technologies, nanoparticles, and nanomaterials applied to the food industry.

Use	Technology	Assignie	Year
Encapsulation, which can be extracts or bioactive compounds for beverages.	Production process, composition, and use of red wine microparticles in powder form concentrated with phenolic compounds, anthocyanins, and resveratrol with antioxidant activity – BR10 2023 018854 0	IPT/ Federal University of Jequitinhonha and Mucuri Valleys (BR/MG)	2023
	Nanocapsules containing microemulsions - EP2618926	Lipotec	2010

Nanoparticles for inhibiting food spoilage.	Cannabinoids encapsulated in nanoparticles and methods for their production and use - EP4167976	Nurevelation	2021
	Application of porous materials for inhibition/interruption of bacterial quorum sensing - US20170251674	OIL DRI of America	2017
Nanomaterials for active packaging	Coatings for food products - SG10201913771P	Oregon State University	2018
	Multilayer articles - CA3100673	MELITTA Unternehmensgruppe Bentz e Melodea da	2019

Source: Prepared by the authors (2025).

Based on the selection of patents for nanoemulsions, nanocapsules, and nanomaterials involving “food/foodstuffs/beverages” between 2015 and 2024, technological production based on data from granted and pending patents points to a 171.08% growth in nanoemulsions; a 72.73% reduction in nanocapsule protections; 136.83% growth in nanoparticles; and 184.83% growth in nanomaterials.

It is important to emphasize the relevance of the use of nanocapsules, nanoparticles, and nanoemulsions in the food and beverage processing phase of the upstream supply chain industry. These industries also include nutraceuticals, which have secured and pending patents. The latter is dedicated by 18.67% to the production of vegetable strata, their duplicates, or artificial derivatives, according to the international patent classification index (IPC) - A23L 33/105; 11.05% for additives, such as dietary fibers (IPC A23L-033/10); and 8.25% applied to altering the nutritional content of foods, creating dietary products, and methods for their preparation (IPC A23L 33/00).

In the production phase of the supply chain, which ranges from raw material processing to final product manufacturing, nanotechnology is extremely beneficial for creating materials that are more suitable for perishable products, which will be stored for a period and exposed to shelf life, considering the specific logistics of each sector. The use of nanomaterials and nanoparticles favors the development of coatings or films for food and beverages, which can preserve aroma and offer protection against external and internal barriers, such as fungi and microorganisms. In addition, these materials can improve handling, as well as increase the quality and durability of an agricultural or processed product, integrating the composition of smart packaging, which includes nanosensors and/or time, temperature, or pH markers.

An example of this is smart packaging that uses indicators or calorimetric nanosensors to detect deterioration through color change, as described in Indian patent no. IN202541073660 and Brazilian patent no. BR 102018071458. In the set of granted and pending patents, the application of nanosensors allows smart packaging to identify the presence of vitamins, gluten, lactic acid, among others. In the first five-year cycle, from 2015 to 2019, nine patents were protected; in the second five-year cycle, from 2020 to 2024, 29 nanosensor patents were protected, representing an increase of 222.22%. Furthermore, of the 29 patents, 41.38% of the investigations or analyses of materials by optical techniques are conducted by fluorescence or phosphorescence (IPC G01N 21/64).

About active packaging, nanotechnology has aided in the creation of films or sheets (IPC C08J 005/18) and in the use of disintegrating, soluble, or edible materials (IPC B65D 65/46). This type of packaging shows a trend toward incorporating active materials, such as composite films and membranes; laser-marked packaging and cellulose films; cellulose-based antimicrobial packaging; and active packaging materials made from polylactic acid and fabrics. Between 2015 and 2019, 51



patents for active packaging were protected. In contrast, between 2020 and 2024, there was an increase of 174 patents, resulting in an increase of approximately 373%.

To ensure food safety, nanotechnology enables advances in pathogen detection through systems, methods, or devices during the food and beverage processing stage, using a variety of nanomaterials, such as modified gold nanorods (CN106706910), devices and methods for manufacturing and using laser-induced graphene electrodes (WO2021/222250). Toxin detection has evolved, as evidenced, for example, by the development of a matrix chip for high-throughput signal detection using nanoparticles (CN109781705) and the application of artificial intelligence to hyperspectral imaging of food samples (US20240264088).

In the context of food safety in the industrial sector, the application of biofilm inhibitors for bacteria, mold, slime, fungi, or resistant pathogens is relevant for cleaning environments that threaten the safety of operations. An example of this is patent US20190382693, which uses alumina nanoparticles to remove and prevent these biofilms.

In Brazil, according to information from the Innovation Survey (PINTEC) in 2011, 2014, and 2017, the food and beverage manufacturing industries, Research and Development (R&D) in nanotechnologies is of little relevance, which contributes to the scarce number of patents held by Brazilian residents. PINTEC has been monitoring the application of nanotechnology in companies since 2011, through four distinct categories: end user (purchase/acquisition of finished product); integrator user, which incorporates inputs or processes; producer of inputs, products, or processes; and research and development of products, inputs, or processes. Table 4 shows that in 2011, only 19 innovative organizations were able to meet the needs in all four categories. In 2014, organizations typically purchased nanotechnology products or services without making modifications. They also incorporated nanotechnology inputs or processes, but to a lesser extent, they produced inputs, products, or processes using nanotechnology. In 2017, organizations focused on being integrator users. Beverage manufacturers, on the other hand, used nanotechnology even less than end users.

Table 4 - Nanotechnology “Food industry” - Brazil

Year	Total Innovators	Mode of use			
		End users	Integrators	Producers	R&D
2011	19	7	4	6	5
2014	25	16	14	8	7
2017	7	1	6	0	5

Source: Prepared by the authors (2025).

Finally, there are a small number of nanotechnology patents protected by Brazilian residents when compared to the output of other developing countries, such as China, South Korea, Russia, and India. The limited use of nanotechnologies by innovative Brazilian organizations, whether as end users, integrators, intermediaries, or in research and development, according to PINTEC data from 2011, 2014, and 2017, suggests the need for public policies to advance this technology, which is seen as disruptive. Recent actions by the Brazilian government include the Nanotechnology Incentive Program, established by MCTIC Ordinance n.º 3,459 of July 26, 2019, and the Graphene Innovation Program, according to MCTI Ordinance n.º 4,964/21.

3 CONCLUSION



Nanotechnology brings benefits to sustainability in the social, economic, and environmental pillars, due to their integrity during processing, storage, logistics, and shelf life, in addition to contributing to the reduction of food and beverage waste. These practices are aligned with the Sustainable Development Goals (SDGs) of the UN 2030 Agenda. For example, the Zero Hunger and Sustainable Agriculture (SDG2) goal, the Industry, Innovation, and Infrastructure (SDG9) goal, and the Responsible Consumption and Production (SDG12) goal are linked to advances in nanotechnology.

The development of nanotechnologies in Brazil shows how the country uses its biodiversity. This happens with the use of active ingredients in packaging, coatings, nanocapsules, nanomaterials, nanoemulsions, and nanoparticles. These elements are important in helping to grow Brazil's bioeconomy and food and beverage industry. They are also important for technology licensing.

The limited use of nanotechnologies by innovative organizations in the Brazilian food and beverage manufacturing industry, whether as end users, integrators, intermediaries, or in research and development, according to data from PINTEC samples from 2011, 2014, and 2017, suggests the need for public policies to advance this technology, which is seen as disruptive.

Given that Brazilian legal mechanisms to stimulate nanotechnology are recent, further studies are needed to evaluate the strategies applied in Brazilian organizations, especially in the industrial sector, and to monitor the application of nanotechnology.

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Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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