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Systematically Monitoring, Relational Database and Technology Roadmapping for Trends and Innovation Opportunities in Biopolymers

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Abstract: In recent years environmental and sustainability concerns have impacted the global chemical industry and instituted a rush to produce products from renewable raw materials. This dynamic, complex and turbulent organizational scenario, around themes touching on the issue of sustainable development model, was created involving a large number of different actors: chemical/petrochemical industries, agroindustry companies, oil/gas companies, brand owners and end users, biotechnology startups, governments, universities and society. This paper proposed the application of a structured and dynamic method of technological prediction for biopolymers in three levels: systematic monitoring process, relational database and the "alive" Technology Roadmapping visualization tool. The main objective is to identify strategic actions, business models, the latest´s technologies in development, as well as trends in the field of biopolymers in order to support companies on position themselves in this competitive scenario. Furthermore, companies, universities, government agencies and institutions could apply this dynamic and alive methodology to indeed access innovation opportunities, challenges and threats for different industrial segments and to provide dynamic knowledge management collaborating to their strategy including a database crossing for the all organization.

Keywords: Biopolymers; sustainability; renewable; systematically monitoring; forecasting; technology roadmapping; knowledge management; innovation

1 Introduction

The major concerns about the future of the global economy, with values about the environment and society, specifically with climate change, global warming, resource scarcity, population growth, urbanization, digitalization/connectivity, have brought a new goal for companies, consumers, governments and science: sustainability in the economic, social and environmental dimensions. In the last decades, efforts are being directed towards the production of products from renewable raw materials such as biochemicals, biofuels and biopolymers that play a key role in seeking solutions to mitigate their impacts and actions that search for sustainable economic development. Moreover, transitioning to a circular economy rethinks the negative impacts of the linear and traditional economic model to strategies that emphasize the reuse and recycle resources [1-3].

The theme is embedded in a complex, turbulent, constantly changing organizational environment that involves various actors, such as industries, agricultural companies, government, academia, society, among others. Thus, it is observed that a new chemical industry based on biomaterials is in full process of formation, with an industrial structure still undefined and with challenges involved in various phases of the introduction process of this new renewable production axis and parallel to petrochemical/chemical.

The space in renewable chemicals, biofuels and biopolymers is undergoing in structure, configuration, maturation, competition, engaged in the development and production around the world. Crucial factors of business differentiation strategies are being considered such as the advantages related to technologies, management models adopted, strategies of product positioning in the consumer market, integration in the value chain, access to plant biomass and market strategies of entry and growth [4-7]. Significantly new and important developments are being identified, especially in the field of biofuels and bioplastics, which play a crucial role in the modern lifestyle.

The sector has advanced significantly in recent years seeking profitability and differentiated market. There is a growing optimism that the substitution of products from petrochemical sources will expand with the development of technologies, increasing market requirements and overcoming the challenges associated with the transition to the use of plant biomass [8,13]. From the point of view of the final consumer, there is a certain awareness of the adoption of more sustainable consumption habits, awareness of aspects related to recyclability, biodegradability and reduction of the carbon footprint, although it still occurs slowly and with greater emphasis on developed countries, mainly in the segments of packaging and in technical applications including automobile, consumer goods, agriculture among others [9].

Faced with these challenges, government, academia and, above all, business organizations need to develop systematic procedures to obtain and interpret technological and competitive intelligence in a strategic way, in order to expand their capacity to anticipate and adapt to the challenges of innovation, to visualize the technological trends of the global chemical industry, including technological changes that can alter the competitive environment in which they are inserted, opportunities for innovation, the challenges faced and the threats to their product portfolio. Technology Roadmapping (TRM) has gained popularity as a tool for managing the future of technology, building vision and exploring the dynamics of emerging technologies. Some authors have presented the TRM as a strategic, objective and flexible approach to assist in the task of management and planning of innovation. Because it is a flexible method it may be able to integrate and communicate market, product, and technology development strategies in a way related to business goals and over time [4,10-12].

This article presents the application of the technological prospection process structured in three levels: LEVEL 1: systematic monitoring, LEVEL 2: relational database and LEVEL 3: associating the TRM method, allowing the integration of all relevant aspects of the topic biopolymers and the scenario of renewables in time dimension. It will be presented the methodology and a partial view of the TRM, which was developed for 5 years, within the framework of a scientific-technological project cooperation between Brazilian petrochemical/chemical company Braskem and Federal University of Rio de Janeiro (UFRJ). The association of this methodology as support in the strategic planning allows the identification of possible gaps and the convergence between the proposal of the actors, especially the companies, in the present and their future goals.

2 Experimental

The methodology adopted and proposed in this article for the analysis of the renewable scenario, focusing on biopolymers, consisted in structuring the process in three levels, considering the turbulent environment in which the theme develops and on a timeline perspective. In the first level, a method of systematic monitoring and continuous technological prospection was developed about the movements in the biopolymers area, considering approximately 105 different sources of information selected and qualified throughout the process among academic databases, such as books (8%), newspapers (6%), journals (papers, magazines and periodicals-17%), patents (15%), releases and news on specialized websites (16%), the websites of active companies and their annual reports (14%), presentations on technical events (7%), market reports and trends studies (11%), social networking sites focusing on renewable and biopolymers scenarios (6%).

The process as a whole comprises the steps of prospecting, collecting, selecting, organizing and analyzing information available in these various sources of information. The method of technological prospection adopted allows to follow the development of bio derivatives products and their chain, processes and actors with actions for the use of renewable raw materials. In the second and third levels, the information was organized, respectively, in two support tools: relational database and Technology Roadmapping (TRM) in visual and graphic form, presenting the results in a temporal analysis and relating the products monitored with market factors and technology critics. The TRM was structured in the X-axis as a function of time: current period, short term (1 to 5 years), medium term (6 to 10 years), long term (11 to 20 years). The positioning of the product in the time line is associated with its commercialization on an industrial scale. The Y axis considers 4 dimensions for the TRM visualization: 1) Drivers/Market drivers/Applications and Properties (the “purposes”-know-why); 2) Products such as the Biopolymers (the “deliveries”-know-what); 3) Players (the “Actors” such as Companies, Universities-know-who); 4) Technologies (the Resources-know-how, including the R&D efforts, the biomass strategy, the complementary competences, the investments, the supply chain integration.

In this work ten drivers have been identified and have been chosen among others for representing the majority motivation of the actors enrolled in the renewable space: 1) sustainability, 2) climate change, 3) resource scarcity, 4) circular economy, 5) global warming, 6) world population growth, 7) regulatory concerns, 8) environmental and society pressures, 9) urbanization drivers consumption and 10) digitalization & connectivity. The eleven market drivers that have been chosen for biopolymers as the central idea of the technology roadmap were: 1) new modern lifestyle, 2) value chain profitability, 3) biodegradability, 4) recyclability, 5) competitive cost, 6) bio-based packaging, 7) consumer individual needs and preferences, 8) ecofriendly, 9) food contact, 10) ready-to-eat and 11) renewable content. The seven relevant applications as motivators for the market demand that have been monitored in this work for the biopolymers were: 1) packaging (films, shrink films, bottles, molted boxes, pouches, compostable bags, containers, cosmetic), 2) textiles (carpets, clothing, and upholstery), 3) agriculture (films, silage films, greenhouse films, yarn, tapes and clips), 4) automotive (interiors-foam, carpet, acoustic underlay, door panels, sun visors, etc.), 5) electronics, 6) construction (houses, industrial buildings, and infrastructure-roads and railways), 7) consumer goods (furniture, sporting goods, personal care products, mobile phone, laptops etc.), 8) medicine. Related to the properties, sixteen major structural requirements were identified and monitored as drivers for biopolymers, in terms of market demand and/or consumer needs or preferences: 1) higher thermal stability, 2) improving mechanical properties (flexibility), 3) improving gas and water barrier properties, 4) biocompatibility, 5) water resistance properties, 6) high biodegradability in different environments, 7) miscibility, 8) biopolymer processability, 9) sealing ability at lower temperatures, 10) recyclability (chemical, mechanical and energetic), 11) optical properties, 12) electronic components, electromagnetic and electrical properties, 14) fire resistance, 15) damage from sunlight, 16) abrasion resistance.

During the entire prospection process, it was strongly considered their relations, aiming to understand and to describe the scenario of biopolymers, to know their behavior, to recognize the winning strategies, to evaluate opportunities and weaknesses, to identify trends that may have a business impact, identify risk factors, signal new opportunities, access the performance of this new sector of the economy in recent years, and ambitiously seek to make some inference about industry trends over the next 20 years.

The relational database was structured first in MS Excel, after migrated to MS Access and has evolved into a fully customized MS Dynamics CRM, containing approximately 160 fields covering the relevant information about: players profiles, partnerships, drivers’ description and correlation with players and products, products profile, development level by player, total production capacity among others. It was identified nearly 1,200 relations and almost 50,000 data in the relational database, being built based on the information of the products and the companies and their relationships with technologies, plants, and projects maturity stage as a time function. The database structure was built based on the relationship between the player versus product, having the fields in forms that allow: a) to promote the storage of the information collected and analyzed in Level 1; b) enable rapid retrieval of qualified information; c) raise the agile visualization of data prospected and introduced in specific fields in the database; d) promote the prospected traceability information and its revision; e) systematize the process of updating information in front of this complex, dynamic and constantly changing environment; f) generate reports and worksheets capable of enabling the necessary feasibility for the systematic analyzes proposed to evaluate the biopolymers theme; g) convert the collected data into usable knowledge about the renewable environment.

The process of construction of the TRM allows to present in graphic and visual form the constantly updated renewable scenario. The graphic representation of the TRM as a final product was first built in MS Excel, after in MS Visio and then it was migrated to a program named SharpCloud that allows a dynamic visualization analysis, improving the usage of the Technology Roadmapping in the graphic form and getting the proposed strategy in having an "alive" TRM that could be shared with other groups interested in identification of trends, opportunities, threats among others strategic analysis.

3 Results and Discussion

Increasing demand for structured process of technological forecasting, as a significant way for company's decision making, are being pursued and will require an expanding of in-depth analysis of the scenario to get the big picture. The aim of this article was to provide the rationale behind this novelty model of "live" Technology Roadmapping (TRM) based on the three levels of structured process of technological forecasting that allows a 360° research and a better understanding on the complex scenario such as the case on renewable space. In addition, this paper proposed an integration of the most important perspectives into a complete, overall view of factors that impact the actors enrolled with this new challenge and the value of prospected information in order to provide an analysis of all the major issues surrounding renewable scenario with focus on biopolymer.

The prospection process proposed in this paper addressed the opportunity to find the rationale behind the current renewable chemicals and biopolymer rush. It drew a proposed methodology to find the main aspects and incentives to invest in chemical production from biomass, in order to obtain biochemicals, biofuels and biopolymers. This study identified approximately 927 actors or players (not exhaustive) engaged in the development and production of renewable chemicals from biomass around the world with the following category division: 1) companies (54%): big chemical/petrochemical industries, agri-business companies, oil and gas companies, brand owners, end users, biotechnology startups; 2) universities (32%); 3) scientific and technological research institutions and governments (14%). The main biopolymer producing companies and important commercial brands holders monitored in this work (such as Arkema, Corbion, TetraPack, Anellotech, BASF SE, DOW_DuPont, Braskem, P&G, CocaCola, Alpla, Toray Plastics, NatureWorks, Lanxess) are developing ways to create value, such as: a) presenting their value proposition b) clear labeling of products; c) dissemination of life cycle analyzes (LCA); d) ways to communicate performance advantages; e) ways to communicate to final consumers about products with green attributes; e) tools to monitor improvements with the use of bioplastics such as reduction of adverse impacts, increased environmental and social benefits, biomass supply, product processing and marketing. Several reports and market analysis published by important institutions classify the top competitors in biopolymer market according to their criteria. So according to the Transparency Market Research [9], the top eleven companies that were more active in the biopolymers scenario in 2016, by considering their capabilities and potential to grow were: 1) BASF SE, 2) DOW_DUPONT, 3) Plantic Technologies Ltd., 4) ADM (Archer Daniels Midland Company), 5) Nature Works LLC, Novamont SPA, 6) Danimer Scientific, 7) Total Corbion, 8) Galetea BioTech, 9) SolanylBiopolymer Inc., 10) Bio-on SPA, 11) Yiedl10Bioscience Inc. However, in this work it was not the main objective to find the top players, products or technologies but to allow that the proposed methodology and the prospection to be very embracing in order to get as much as possible the weak signals for trend analysis.

Through the prospection process established in this work it was identified 117 products (not exhaustive and split in 67 biochemicals, 37 biopolymers and 13 biofuels) that could be obtained from renewable resources and were monitored in this paper independently of their production capacity, number of producers and other criteria mainly because in this process of looking for trends, new opportunities and threats the all information could be capture for further analysis. The main biopolymers monitored were (not exhaustive): Bio-Polyethylene (PE-100% bio-based content), Biodegradable polyesters, Bio-PET

Polyethylene Terephthalate), Cellulose acetate (CA-50% bio-based content), Epoxies (30% bio-based content), Polyisoprene (IR), EPDM (Ethylene propylene diene monomer rubber- 50% to 70% bio-based content), Polyamides (PA-40% to 100% bio-based content), Butyl Rubber, Poly(butylene adipate-coterephthalate) (PBAT-up top 50% bio-based content), Polybutylene succinate (PBS- up to 100% bio-based content), Polyurethanes (bio-based carbon content-10% to 100%), Biodegradable Starch blends, Polytrimethylene terephthalate (PTT-27% bio-based content), Polylactic acid (PLA-100% bio-based content), Polyhydroxyalkanoates (PHA-100% bio-based content), Polycaprolactone (PCL), Polyglycolic acid (PGA), Polycarbonates (PPC and PEC). Through the database the information prospected for biopolymers allows the creation and development of a "product profile" for each biopolymer monitored with the main information: renewable raw material or biomass (for example sugar cane, sugar beet, soy bean, starch, corn, wheat, solid waste, grain , sunflower), biochemical building block (biochemicals such as: adipic acid, succinic acid, ethylene, butadiene, isoprene etc.), level of value chain integration (for example: PLA-integration from biomass corn and basic components with Cargill, and commodities, building blocks to final products with NatureWorks LLC-Ingeo Biopolymer), main advantages (for example: PLA-carbon monoxide capture, biodegradable, high transparency, shown to the market as a sustainable option), main disadvantages (for example: PLA- requires adjustments in the machine for replacement), applications, recyclability process, main producer countries, time to market, world consumption and production capacity, plant location, planta annual capacity, trade name, final market addressed, type of partnerships (take of agreement, development partner, distributor, end user, key client, feedstock supplier, investor, joint development agreement, joint development of commercial process technology, licensing agreement, licensor, patent assignee, producer).

Besides that, it was possible to extract from the database, with reports about the correlation between players and specific biopolymers (not exhaustive) in order to find trends, opportunities and threats, even with the historical data where the companies gave up from the initiatives were consider as lessons learned in the analysis, besides that considering all kind of relationship not only the producers: 1) Biopolyamide-Ajinomoto, Toray, Arkema, Suzhou Hipro Polymers, Basf, Cathay Biotechnologies, DSM, Mercebes Benz, Dupont, Elevance, Evonik, Rhodia, Avantium, Teijin, Iowa State University, Radici Group, Rennovia, ADM (Archer Daniels Midland Company), EMS-Grivory; Teijin, Verdezyne, 2) Green Polyethylene-Braskem, Amerplast, Dow Chemical and Mitsui (that give up on the partnership and postponed the plans for Brazil), SABIC, Elopak, 3) Bio-PET (Polyethylene Terephthalate) - Annelotech, Suntory, Avantium, Cocacola, Gevo, Indorama Ventures, Pepsico, Toray, Virent, 4) Polyhydroxyalkanoates (PHA)-BASF, BioOn, Biomatera, Trellis Earth, Kaneka, Ikea, Lanzatech, Meridian, Metabolix, Mitsubishi, Newlight Technologies, Ningbo Tianan, Oakbio, PHB Industrial (Biocycle), Tianjin Greenbio Materials, 5) Polylactic acid (PLA)-BASF, Cargill, PTT Chemical, NatureWorks, Trellis Earth, COFCO Group, Corbion-Purac, Danimer Scientific, Dow Chemical, DSM, Fkur, Futerro, Galactic, Indorama Ventures, Meridian, Pyramid Bioplastics, Synbra, Sulzer Chemtech, Total, Toyobo, University of Leuven, Teijin, Solegear, Metabolix 6) Bioplastics, Biodegradable Starch blends-BASF, Cardia Bioplastics, Trelis Earth, Bemis, Ecosynthetix, Huhtamaki, Plantic, Novamont, Wuhan Greenplas, Starch Tech, Solanyl Biodegradables, Limagrain, 7) Butyl Rubber-Gevo, Lanxess, 8) EPDM-Ethylene propylene diene monomer rubber-Freundenberg, Lanxess, Braskem, 9) Epoxy Resin-Dow chemical, Solvay, 10) Polybutylene succinate (PBS) Ajinomoto, Amberworks, Bioamber, Faurecia, Metabolix, Mitsubishi Chemical, Hoescht, Myriant, ShowaDenko, PTT MCC Biochem, NatureWorks, Sinoven Biopolymers, 11) PEF (polyethylene furanoate)-Avantium, Coca-Cola, Danoe, BASF, Canon, Dupont, Eastman, Furanix Technologies, Hitachi, Mitsubishi Chemical, Natura, Perstop, Stanford University, Toray, University of Jiangnan. 12) Biodegradable polyesters-ADM, BASF, DuPont, Henkel, Danimer Scientific, Valagro, 13) PPC and PEC-Polycarbonates-Bayer, Novomer, SK Energy, 14) Green Polyuretanes-Covestro, Reverdia, Annikki, Dow Chemical, Henkel, Benteler, Invista, BASF, Genomatica, Xuxhuan Chemical.

Straight for biopolymers, the main analysis and relevant factor identified, through the proposed methodology of technological prospection of this article, is related to the fact that a final product based on renewable raw material will not succeed only because it is bio-based. What makes biopolymers attracts globally is the association of the fact that it is produced from renewable raw material, moreover because the product has specific and relevant properties associated with it, so that it can succeed in new and existing applications. The most prominent for biopolymers success is the link between producers´ business models and their environmental impact reduction, customers desires and products performance advantages. From the structured prospection process proposed in this paper, a vast number of huge analysis could be done.

A dynamic database storing and the "alive" Technology Roadmapping of Biopolymers allow that the information prospected could be organized in such a way that the main inferences such as presented in this article, moreover the relationships and trend analysis could be able to be created. In Fig. 1, it shows the partial graphical representation of the TRM of Biopolymers developed in this article by the authors as a visualization and useful communication tool, for all the organization as a learning and living process. Throughout the TRM graphic form it is possible to identify the drivers, market drivers, applications and properties as motivators (purpose-know-why) that are related with the companies and the products, as well as the products delivered (know-what), with the player enrolled (know-who) and the technologies (know-how).

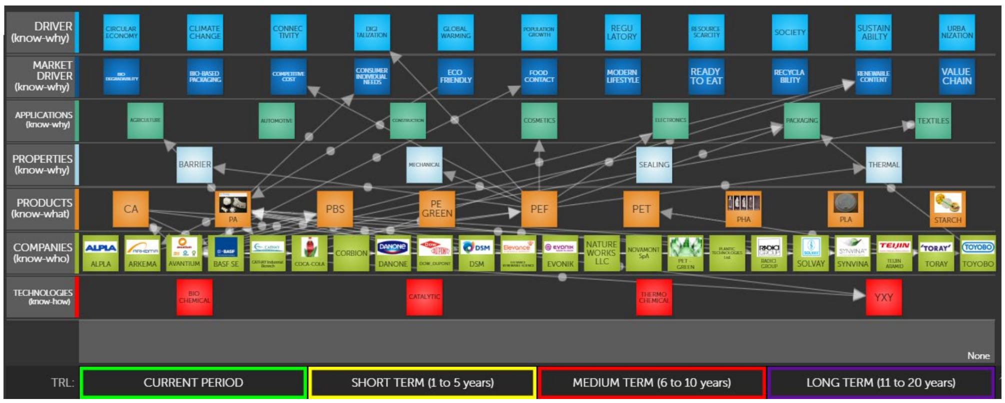

Figure 1: Biopolymer Technology Roadmapping-partial view due to the large amount of data. Source: Own elaboration in SharpCloud

The potentiality of the process established in this work, could be observed by the proposed relational information showed in Figs. 2 and 3 that highlights examples of the possible relationships for a company (Avantium) and for a biopolymer (Green Polyamide), respectively.

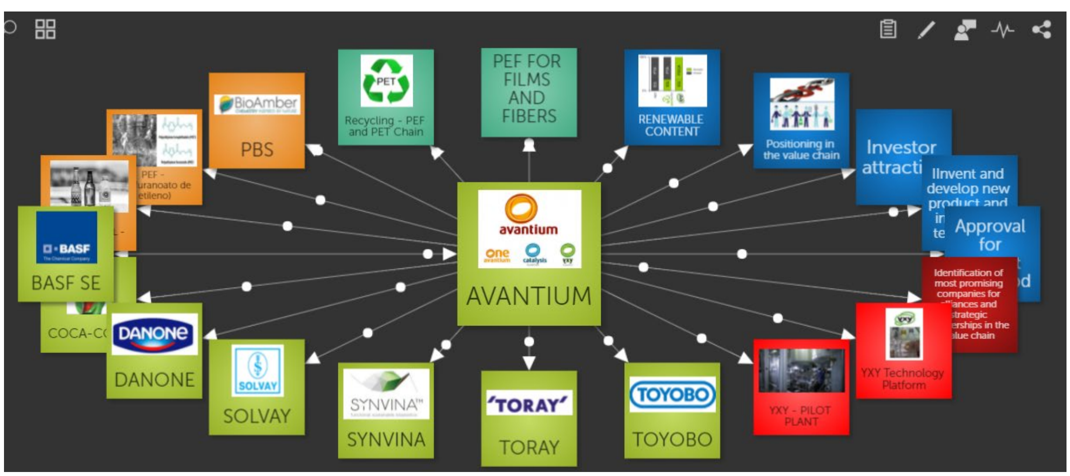

Figure 2: Avantium analysis of the relational with drivers, technologies, properties and in partnership with other players-Source: Own elaboration in SharpCloud

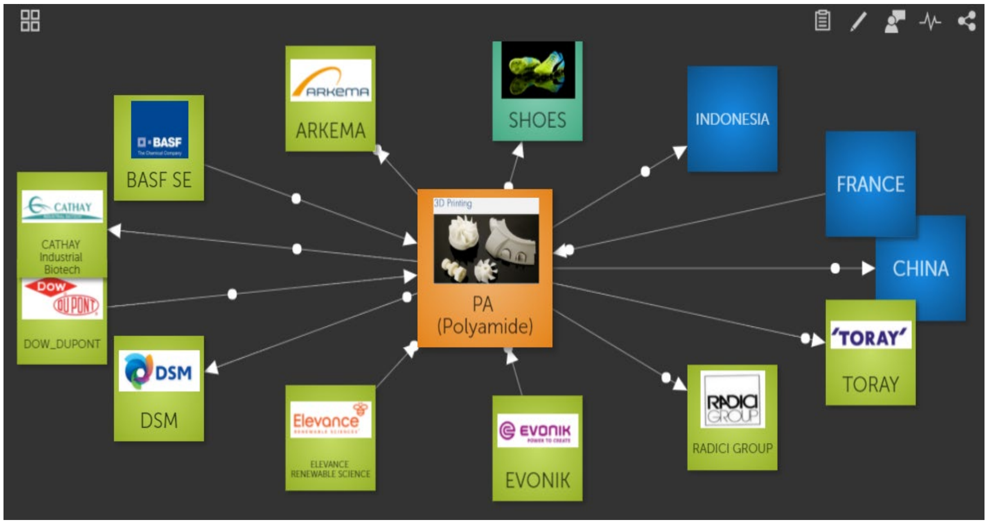

Figure 3: Green Polyamide relational data with other players, relevant applications and countries-Source: Own elaboration in SharpCloud

The example of Fig. 2, highlights the relational information about Avantium Company that is a chemical technology company based in the Netherlands, consolidated in the year 2,000, coming from Royal Dutch Shell. The company uses its expertise in catalysis and crystallization to develop new chemical processes with a renewable focus. Avantium is working on the development of FDCA for application in polyesters and PEF in particular. Avantium currently has a pilot plant in operation, with a capacity of 40 kta, located in Geleen, The Netherlands. For the construction of this plant, the company received 30 million euros from investors such as Sofinnova Partners, Aster Capital, De Hoge Dennen, Aescap Venture, Capricorn Cleantech Fund, ING Corporate Investments and Navitas Capital. Economic Affairs, Agriculture and Innovation (EL & I) in June 2011. The company entered in a joint venture with BASF to produce the FDCA (2,5-furanedicarboxylic acid or furandicarboxylic acid) and PEF (polyethylene furanoate) as an excellent alternative to substitute PET (polyethylene terephthalate) in films and plastics bottles. In this way, it will have its large-scale production and global commercialization to compete with the consolidated petrochemicals products. The drivers of its strategy and how Avantium uses its expertise in catalysis and crystallization for the development of FDCA (2,5-furanedicarboxylic acid or furandicarboxylic acid) for application in polyesters and PEF (polyethylene furanoate) substitutes PET (polyethylene terephthalate), as well as superior properties (mechanical, thermal and barrier).

The large-scale production of PEF means the reducing of greenhouse gas emissions and besides the reducing of the use of non-renewable energy compared to PET. For the analysis of Green Polyamide (Fig. 3) it is possible to evaluate the relational data with players, relevant applications (shoes, among others) and countries (Indonesia, France and China). The advantage associated with the dynamic visualizing tool is that different and important analysis could be obtained easily from the prospected data, helping the right communication of the information analyzed at the right time for major decision makers, helping the exploration and exploitation of the opportunities for innovation and knowledge management.

Indeed, important drivers is affecting the dynamics of the market, the demand and the adoption of biopolymers in place of petroleum-based polymers. Through the process of structured prospecting, that the period that comprised the years 2006 to 2010 was marked by the appearance of several initiatives mainly by important chemical companies, such as PTT Chemical in partnership with NatureWorks, BASF in partnership with Heritage Plastics, DuPont and ADM, also by government agencies in searching for the identification opportunities in the theme, emergence of technology-based on new born companies in search for technologies validation, identification of most promising companies for alliances and strategic partnerships in the value chain, indeed searching for the contribution of governmental and private financial resources to the proof-of-concept stages and pilot-scale plant construction, licensing of patented technologies for large chemical companies with experience in the value chain, as well as to enable scaling process, including constant attractiveness analysis by bio-based monomers and each biopolymer in the value chain. Through this work it was identified that from the total of 191 partnerships prospected, approximately 134 (70%) was established in the years between 2006 and 2010. It means that one important conclusion could be highlight for the biopolymer scenario about the business model used by the players: required partnerships seeking for complementary competences in the learning process. Furthermore, at this period it was observed that government support for adopting bio-based materials was not encouraged as expected, because they had noticed that the commercialization of these products had been somewhat limited due to their high cost, lack of viable markets and the need for more recycling initiatives for sustainable procurement.

The period between 2010 and 2013 was marked by constant announcements of complex networks formation and also cooperation between the actors involved through mergers, acquisitions and strategic partnerships searching for complementary technological and marketing skills, indicating the trend by the high level of integration in the value chain of this sector, the developing startups in pilot scale plants and demonstrative scale, new announcements of public and private capital contributions, searching for acquisition and control of the best and new technologies for the plant biomass processing as for commercial-scale production, identification of strategic developments, competitive analysis and perspective on the upcoming developments, as well as the regulatory scenario that impacts directly the biopolymers market.

The period from 2014 to 2020 is marked mainly by actions related to the conclusion of the announced plans implementation and the increase in demand for biopolymers due to the new modern lifestyles of people around the world. Although on the other hand, it was observed new postponement of plans for the construction of new commercial plants for production of biofuels, bioproducts and biopolymers on a commercial scale by the companies, on the all value chain and even cancellation of strategic plans, including announcing other strategic moves against a new economic reality, mainly due to the low oil prices and its fluctuation along the next years. Furthermore, it will be possible to observe the effective possibility of identifying the actors, among the major chemical corporations and the major competing players, that have maintained their actions related to sustainable economic development. However, the rigid environmental regulations trigger the use of biopolymers products, so regulatory concerns are important drivers that could impact positively the low political support and restrictions due to security and economic for biopolymers that are current being observed. Due to the shift in consumers behavior, new developments in ecofriendly packaging, packaging applications for antimicrobial purposes, ready-to-eat-packaging food are being demanded, representing opportunities in the biopolymers field and a motivation for the improvements in the food packaging industry. Moreover, they are looking for positive experience based on their individual values, needs and preferences beyond the well-known demographic factors, such as age, gender, allowing another kind of market analysis. The next period will be impacted by the increase in consumer preference by bio-based packaging for beverages and food, due to the recognition of their sustainable properties, increase in environmental legislation and by increased in governmental interest and incentive in public and private investments providing market growth for bioplastics also in potential applications such as: agriculture applications (films, mulching, irrigation and greenhouse components), medical, pharmaceutical, construction and automotive.

Through the tree level method to the renewable area the authors could be shaped an updated and trustworthy prospection system for appropriate monitoring that allowed the analysis of bio-based chemicals, biopolymers and biofuels in terms of business models, competitive intensity (number of players), industry convergence (partnerships, drivers), technological competition (technology readiness level), customer requirements (application, segments, properties as market drivers), consumer wishes, dynamics capabilities, competitiveness, complementary competences, disruptive technologies (new developments, patents and research lines) and forecasting of future trends for supporting the identification of the best opportunities for innovation, furthermore challenges and threats in bio-based raw materials, biofuels and biopolymers.

4 Conclusions

Many actors around the world realized that to position itself with some security in environments where "change is the rule", the organizations need to stay up-to-date on technological and market trends in the global environment and to consistently revisit their business strategy and sustainable value propositions aiming to develop systematic procedures for obtaining and interpreting strategic intelligence that expand their ability to maintain competitiveness and to anticipate and/or adapt to the challenges of the innovation to seize these opportunities. Therefore the systematic and structured three-level technological prospecting process on renewable area with biopolymers in focus proposed by the authors in this article, has constituted a comprehensive tool and a new way and suggested forecasting for important strategic actors, aiming the effective data integration for the correlations accomplishment, trends analysis, technological intelligence and even applicable to other industrial themes and segments, aiming to reduce uncertainties, mitigate risks, identify the movements of the main actors involved in this effervescent theme, overcome technological and marketing challenges, relevant issues, competitors, universities, government actions, identification of new research lines, relevant researchers, patent analysis, strategic movements, business models, value chain integration, relevant documents and global actions for a sustainable society.

There is a true expectation that in the medium and long term, biopolymers must bring gains and responsibility for the entire value chain, in order to address the major challenges in the modern-day world. Although there is plenty of work to be done to maximize the biopolymers value proposition, mainly because their adoption should be facilitated as consumers rise in demand for bio-based products and the industry moves towards improving new and existent production technologies, increasing installed capacity, addressing the challenges for scale up, going through mergers and acquisitions, establishing strategic collaborations in order to find complementary competences, launching new products and developing new applications that present advantages over conventional polymer resins, both by producers and consumers by increasing competitiveness with their petrochemical counterparts.

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