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TECHNOLOGICAL MANAGEMENT FOR THE DEVELOPMENT OF PROTOTYPES IN THE PLANTAIN AGRIBUSINESS CHAIN. A look from S-Curves, the Patent-Papers matrix and Hypecyle

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Abstract– ***Agroindustrial sectors in developing countries requires identifying technologies and innovations and applying technology management methods to enhance efficiency, competitiveness, and quality of life for agricultural producers and their associations. The objective of this paper is to identify and prioritize technologies and innovations related to the Plantain Agroindustrial chain as support for technology transfer processes. This study applies technological management methods to evaluate the feasibility of emerging prototypes in the plantain agri-food chain, using S-curves, inflection points from time series of papers and patents, Patent-Papers matrix, and Hype Cycle. The methods used include establishing critical surveillance factors such as plantain- biopolym, biofilm, biodegrade, thermoplast, Scopus search equations, time series analysis, nonlinear regression models in Sigmaplot, Python for validation of inflection points, text mining, NLP, cooccurrence matrices. 27 emergency components were identified through the Hype Cycle, in the S curve, the inflection points in 4 time series generated values prior to 2025 and only 1 equation related to biodegradable polymer blends, thermoplastic starch, and biodegradable film generated a turning point in papers in the year 2029, the patent papers matrix allowed to classify the topics and technologies analyzed in four quadrants according to the papers and patents axes, finally the emergency analysis obtained with the vantage point software identified to China, Thailand, and India as main producers with a particular focus on migration to sustainable and safe markets, in the American continent countries such as Brazil, Mexico, the United States, Colombia, and Ecuador are countries with constant and growing research report.***

Keywords-- Innovation management, Plantain, S-curves, Patent-Papers matrix, Hype Cycle.

I. INTRODUCTION

The plantain agroindustrial chain is considered one of the most important worldwide, ranking as the fourth most important after wheat, rice, and corn [1]. In figures from the Food and Agriculture Organization of the United Nations (FAO), plantain cultivation reached production volumes in 2018 of 39 million tons, with the African continent being the main supplier of this fruit worldwide [2]. Plantain cultivation is considered a crop of great economic relevance for the fight against poverty, representing 13.1% of the Gross Domestic Product (GDP) in countries such as Ghana and being a source of income for more than 213 thou.sand families in countries such as Colombia [2]; [3]. Similarly, it is considered an important alternative to ensure food security in the world, due to its nutritional content, with energy contributions between 6.3-15.3%, protein (5.9-30.2%), and minerals such as calcium (7.8-16%), iron (9.2-23.3%) and zinc (28.5-33.7%) [4].

In this article, we address the study of new methodologies TM applied to prototypes derived from this chain, with a focus on key aspects such as technology trend analysis using tools such as S-curves, inflection points, Patent-Papers matrix, emergency components and the Hype Cycle or over-expectation cycle.

The methodology is structured in three fundamental phases, focused on key aspects of the TM and innovation process. The first phase was the planning and collection of relevant information where the critical factors of surveillance (CFS) were determined, which were validated with the support of experts and then proceeded to generate the search equations. In phase two, 5 search equations were built in Scopus that generated 5 time series for papers and patents, the text mining software Vantage Point was also applied through techniques such as natural language processing - NLP and co-occurrence matrices, in phase 3, S curves were generated for the time series and the inflection points were calculated with accumulated series of papers and patents, these calculations were carried out with the free version of Sigmaplot software and with Python libraries and code for nonlinear regression through the logistic model, in this last phase the patent - papers matrix was also built with the data of the inflection points and two Hype Cycles for emergency component analysis.

II. THEORETICAL FRAMEWORK

Plantains and plantain are agro-industrial products of importance in terms of food security in the world promoting employment and rural economy as well as that transformation because they are found in tropical and subtropical countries of the world, the main production areas are in Asia, Latin America, and Africa with an approximate annual production of 44 million tons [5]. For its part, the Plantain-plantain sector, achieved a market value of USD 25 billion globally, with a compound annual growth rate of 4.5% for the period 2022-2027 [6]; in terms of foreign trade, plantain exports reached a value of USD 575 million by 2022 [7], with Ecuador, the Philippines, Costa Rica, Guatemala, Colombia, and the Dominican Republic being the main exporters of this fruit [8].

In this way, it identifies the importance of contributing with a useful approach to the understanding of key aspects within organizations, with a multidimensional approach that will cover crucial aspects such as knowledge, technology, innovation, development, research, and resources, among others, with a series of own strategies that are adapted to each dimension [9]. The TM in parallel or with the use of TW as an organized process of capturing, analyzing, and converting external information into knowledge [10], emerges as an essential tool in this study seeking to boost innovation by detecting opportunities and new ideas applicable to the plantain agroindustrial chain and the different by-products derived from it. Similar studies conducted in other chains such as cocoa by [11], avocado, plantain, Plantain, and vegetables and with other agroindustrial by-products such as tanning in the study by [12] state that TW in conjunction with analyses such as S-Curves, to provides some advantages by way of anticipating the market, reducing risks, fostering cooperation and generating new projects, among other benefits [13]

For the development of this study, the methodology is divided into three essential phases that focus on fundamental aspects of the process. As a first phase in the technological, market, customers, suppliers, environment, products, and competitors' dimensions, the CFSs proposed by the researchers are identified that allow optimizing and planning decision-making [14]. These become an input to perform the search equations of interest for the present study, accompanied by the use of different Boolean operators for the search in the Scopus basic research database, which includes journal articles, books, patents, and integrated websites, in conjunction with metrics of research interest. Further, to present information through quantitative and qualitative analyses in technical, market, and patent areas, use is made of Vantage Point software version 15. 1, which offers a wide variety of highly practical benefits, where it completes the data, for analyzing and routing them to further analysis and discussion [15], similarly, its relevance and use have been employed in a variety of current studies obtaining promising results [16].

With the findings from the number of articles and patents retrieved, use is made of the S-curve methodology with its various applications, ranging from the projection of the performance of new technologies to market penetration studies, population change forecasts, macro and microeconomic analysis, as well as the evaluation of technological diffusion mechanisms [17. These models, based on S-curves, play a crucial role in understanding the dynamics of change by revealing patterns, causes, probabilities, and possibilities in social, political, economic, and technological systems [18]; [13].

In order to evaluate the impact of new technologies from an organizational perspective, the Hype Cycle methodology is used, concluding and highlighting its contributions and suggesting possible directions for future research. This model is built by merging equations and bell-shaped curves regarding expectations, established as a sudden positive and irrational response to the existence of a new technology. Experts [19], They argue that the configuration of this curve is due to three phenomena in human na-ture, the attraction to novelty and the desire to share it, social contagion and the generation of new knowledge in decision-making, and that these phenomena can also enhance a new technology [20].

Introduced by Gartner Inc. in 1995, the Hype Cycle model traces an applicable trajectory that illustrates the evolution of technology relative to expectations and the viability of technological value over time [21]. Its relevance highlights that the S-curve-based diffusion model has been dominant in innovation evolution research and practice for nearly six decades and despite its wide acceptance for over 20 years, the academic literature has offered little more than confirmation of the hype cycle phenomena as reported by [22].
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On the other hand, to improve the competitiveness and organizational innovation capabilities of companies in general and in the current study of the plantain agroindustrial chain, in phase 3, the innovation capabilities as a crucial axis based on a detailed analysis of the reconstruction of their temporal evolution. For this it is essential to address key aspects such as

vision, leadership, external relations, and organizational structure, from the perspective of both the offer and those who demand it, having a clear vision of its attributes and values. For this purpose, we take as a basis the modified Business Innovation Test of the Catalan Institute of Technology (CIT, 1999) and its five key factors included in its original version: Innovation Strategy, Innovation Strategy Deployment, Innovation Culture, Innovation in the Value Chain and Innovation Results; which provide a set of perspectives and approaches in a comprehensive framework to understand and address innovation capabilities in the business context. The relevance of this diagnosis is also reflected in the study of [23] following the definitions provided by [24]; [25], in conjunction with the approach of [26] in which strategy, specific competitive conditions, and environment are factors that must be adjusted to the complex process of interaction of all factors influencing the agribusiness chain, such as its scope, size, scope of action, among other aspects, where additionally [27] suggests that all this must consider as a basis the effective combination of resources.

Finally, in the prototype model for innovation management in the case study CPSR (Center for Pharmaceutical Science and Research), several tools were implemented to evaluate its technological and innovative capacity. These tools include the project-based Technology Management Methodology (TMM) [28], strategic foresight with the (MIC-MAC) method, the "Improve self-assessment" tool, the Albacete innovation self-diagnosis, and the Catalonia business innovation test. This set of tools is used to determine the current state of the technological and innovative capacity of institutions and companies, although they can also use other methodologies and tools to select TT mechanisms, products, and minimum viable models to align with technology transfer.

An important aspect to highlight is that, through the analyses, diagnostics, and profiles generated by these tools, gap variables are identified and significant relationships or impacts are established between them, prioritizing variables and organizing them by thematic groups, for each identified group, improvement plans, and specific innovative projects are proposed aimed at closing the detected gaps [29]. Accordingly, the objective of this work was to apply TM methodologies to analyze the life cycle and assess the technological feasibility of emerging technological prototypes in the agri-food industry.

III. METHODOLOGY

The three phases proposed in his study are focused on key aspects of the process. Its structure was previously tested by [12], according to the guidelines suggested by [30] where for its development the stages of planning, capture, and search for critical surveillance information are established, the stage of analysis and generation of intelligence composed of the analysis of S-Curves, Patent-Papers Matrix and Hype cycle, a phase where the behavior of the research is obtained, evidenced, reported and compared over the years about previous agroindustrial studies on the subject, the Figure 1 shows the phases of the methodology.

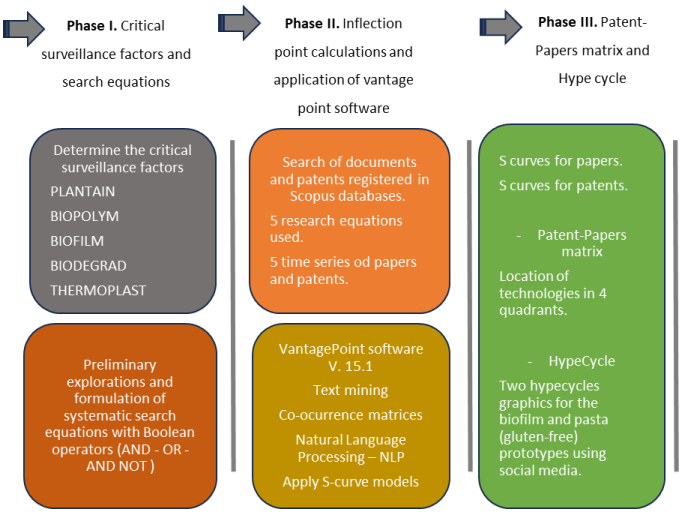

Figure I. Proposed methodology. Adapted from [23]

There are different reasons to apply the S-Curves, Patent-Papers Matrix and Hype cycle techniques, as for S-Curves, this method based on time series of accumulated data from papers and patents has proven its usefulness in decision making about the phase in which a technology is, the right time to exercise technological law and intellectual property mechanisms and monitoring and investment strategies, the Patent-Papers Matrix allows refining inflection point calculations through S curves, generating 4 quadrants where technologies are located by their opportunities, providing valuable information in a single table or matrix on technologies with future inflection points on the axes of papers and patents, finally the Hype Cycle allows identifying emergency components based on social networks based on the year of occurrence as a complement to the exclusive analysis of papers and patents.

Phase 1: The CFS identifying the different topics and fundamental requirements for the development of the article was established by researchers from the Agroindustrial Technological Development Center of the Technological University of Pereira (CDTA-UTP) with experience in agroindustrial engineering, process engineering, and agroindustrial chains with postgraduate training and with the help of the results obtained from the prospective study of the plantain chain 2032 [31].

Preliminary explorations were carried out continuously, followed by the formulation of the systematic search

equations, using as sources the documents and patents consigned in the Scopus databases. In both platforms, the search was performed in the title, abstract, and keyword fields (TITLE-ABS-KEY) and finally, a filter was applied to select the reports obtained from 2001 to 2022. The elaboration of the search equations was articulated with the strategic use of the text mining software Vantage Point version 15.1, to perform a complete evaluation of all the documents, involving an exhaustive reading of the articles and enabling a detailed analysis. Through this tool, results were generated in different formats, such as varied graphs, tables, and visual representations, facilitating the interpretation and understanding of the information extracted.

Phase 2: 5 search equations were built in Scopus based on critical surveillance factors:

- (TITLE (("Plantain" OR "plantain" OR "dominico harton" OR "musa*")) AND TITLE-ABS-KEY (("extrusion" OR "blown" OR "reactive extrusion" OR "coupling agents" OR "chain extenders" OR "plasticizers")))
- TITLE-ABS-KEY ("biodegr* packag*" OR "biodegr* film*") AND (TITLE-ABS-KEY ("plantain" OR "musa*" OR "Plantain"))
- (TITLE ("biodegrad* polym*" OR "biodegradable polymer blends" OR "thermoplastic starch") AND TITLE-ABS-KEY ("biodegrad* bag*" OR "biodegrad* film*") AND NOT TITLE-ABS-KEY (pharm* OR medic* OR biomed* OR genet*))
- TITLE (bioplast* OR biopolym* OR biofilm* OR "biodegrad* plast*" OR thermoplast* OR "biodegrad* mater*") AND (TITLE (plantain OR plantain OR "dominico harton" OR "musa*")) AND NOT (medic* OR biomed* OR therap* OR implant* OR dent*)
- TITLE (bioplast* OR biopolym* OR biofilm* OR "biodegrad* plast*" OR thermoplast* OR "biodegrad* mater*") AND (TITLE (plantain OR plantain OR "dominico harton" OR "musa*")) AND NOT (medic* OR biomed* OR therap* OR implant* OR dent*)

These equations generated 5 time series for papers and patents which are the input for calculating inflection points through nonlinear regression with the free version of sigmaplot software and validation with Python with the pandas, numpy, matplotlib, seaborn libraries and a code for the sigmoid function,

Was also applied the text mining software Vantage Point through techniques such as natural language processing - NLP for word cloud, co-occurrence matrices and emergency component identifying the main attributes associated with technological emergence, which refers to a technology that is still at an early stage of development and is expected to benefit various sectors of the economy and society generating various economic benefits in the coming years.

Phase 3: Effective innovation and technology management are essential for the sustainable development of enterprises in the modern era. This article explores and analyzes three key methodologies applied in the plantain agroindustry chain: S-curves, Patent-Papers matrix, and Hype cycle, highlighting their relevance in the context of strategic innovation management.

The data collected from articles and patents were organized in tables, detailing their respective years and quantities. These values were accumulated to enter them as input parameters in the Sigmaplot 30-day free version software. Continuously, by nonlinear regressions, the program's 13 models were applied to derive the S-curves. The validity and approval of the curves were done considering statistical data generated by the software, such as adjusted R2, T-value, P-value, and Durbin Watson statistic. This validation process was supported by criteria previously evaluated in different studies and application areas [18]; [32]; [33]. Continuously, when the second derivative was obtained for each equation, the life cycle analysis of the selected technologies proceeded, taking into consideration the inflection points obtained to select the most appropriate curves providing a more detailed analysis [34]

The Patent-Papers matrix emerges as a comprehensive method to evaluate the effectiveness of the research, development, and innovation (R&D&I) strategy, by examining the relationship between scientific publications and patents, this tool facilitates the strategic alignment of research with the innovation objectives of organizations or associations, offering a broader perspective for future decision making. Its interpretation consists of reading a matrix with four quadrants, where the X-axis represents the inflection point for paper and the Y-axis represents the inflection point for patents. For the construction of the matrix, the year in which the calculations were made concerning the timelines obtained through the search equations is used.

The Hype cycle methodology, on the other hand, provides a systematic framework for evaluating the adoption of emerging technologies over time. With phases including inflated expectations, depression of reality, and established productivity, the Hype cycle becomes a crucial tool for informed decision-making on the adoption of new technologies in the business environment. The effective application of these methodologies requires a holistic approach, where the combination of these tools provides a complete vision for strategic decision-making in innovation management [19].

IV. RESULTS

In the phase 1, the results stage is broken down and interrelated with each of the three established methodological phases. The initial phase of planning, gathering, and searching for information was crucial in the construction of the article, being a primordial input for each of these phases. The CFSs, proposed by the experts, which are framed by the topics and needs for the agroindustrial chain and the development of the

present study, drove the construction of the search equations. Following the compilation and analysis of the CFSs, the search equations to be entered in the Scopus database were prepared, with which the information was identified, selected, categorized, and processed.

As for phase 2, the keyword cloud is presented below in figure II, with some of the most relevant aspects for this study.

Figure II. Keyword cloud. Obtained using VantagePoint.

The Table I presents the search equations used to determine the numbers of articles and patents registered in Scopus with their respective years of infection allowing understanding of the behavior and status of the technologies over time.
Table I. Research situations for papers, patents, and inflection points.

Equations	Inflexion point Papers	Inflexion point Patents
(TITLE (("Plantain" OR "plantain" OR "dominico harton" OR "musa*")) AND TITLE-ABS-KEY (("extrusion" OR "blown" OR "reactive extrusion" OR "coupling agents" OR "chain extenders" OR "plasticizers")))	2021	2024
TITLE-ABS-KEY ("biodegr* packag*" OR "biodegr* film*") AND (TITLE-ABS-KEY ("plantain" OR "musa*" OR "Plantain"))	2023	No convergence
(TITLE ("biodegrad* polym*" OR "biodegradable polymer blends" OR "thermoplastic starch") AND TITLE-ABS-KEY ("biodegrad* bag*" OR "biodegrad* film*") AND NOT TITLE-ABS-KEY (pharm* OR medic* OR biomed* OR genet*))	2029	2009
TITLE (bioplast* OR biopolym* OR biofilm* OR "biodegrad* plast*" OR thermoplast* OR "biodegrad* mater*") AND (TITLE (plantain OR plantain OR "dominico harton" OR "musa*")) AND NOT (medic* OR biomed* OR therap* OR implant* OR dent*)	2024	2021
TITLE (bioplast* OR biopolym* OR biofilm* OR "biodegrad* plast*" OR thermoplast* OR "biodegrad* mater*") AND (TITLE (plantain OR plantain OR "dominico harton" OR "musa*")) AND NOT (medic* OR biomed* OR therap* OR implant* OR dent*)	2023	2021

Own elaboration.

Once these data were obtained, the application of 13 nonlinear regression models with the respective accumulation of data by year and with the help of the Sigmaplot free version software and the application of the hypothesis test with T and P values together with the calculation of the Durbin Watson values was carried out. The results, evidence the technologies that stood out when applying the stipulated methodologies and where the performance potential and status of the technologies are determined.

As a complement to the development of the S curves, validation of results and additional analysis will be carried out through Python,

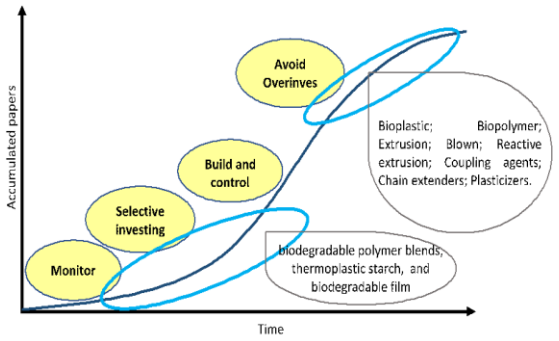

Figure III. Life cycle and evolution of technology. Key factors found. Adapted from [35].

Figure III shows that the topics related to four of the five equations are in the maturity phase, meaning the inflection points have already occurred in years prior to 2025. While the topics related to one of the search equations, related to biodegradable polymer blends, thermoplastic starch, and biodegradable film, are found before the inflection point. For these topics, the growth rate in papers and interest in research and development is still high, which may represent a significant opportunity for the development of plantain prototypes in these technologies.
Similarly, when analyzing the S-curves of the patent time series, it was observed that inflection points were reached in all five equations in years prior to 2025. Therefore, from the perspective of the technology-related patent growth rate, they are in the maturity phase.

Subsequently, regarding the results of phase 3, the Patent-Papers matrix illustrated in figure IV is implemented to evaluate the effectiveness of the R&D&I strategies. For its construction, the time obtained with the applied search equations was considered this is based on the year 2025,

where the calculations were performed. Its construction is based on the inflection points/years obtained in table I such that, if the inflection points were less than 2025 in papers and patents, the equation is established in the lower left quadrant and those search equations whose inflection points yielded results in papers beyond 2025 and patents before 2025, were in the lower right quadrant.

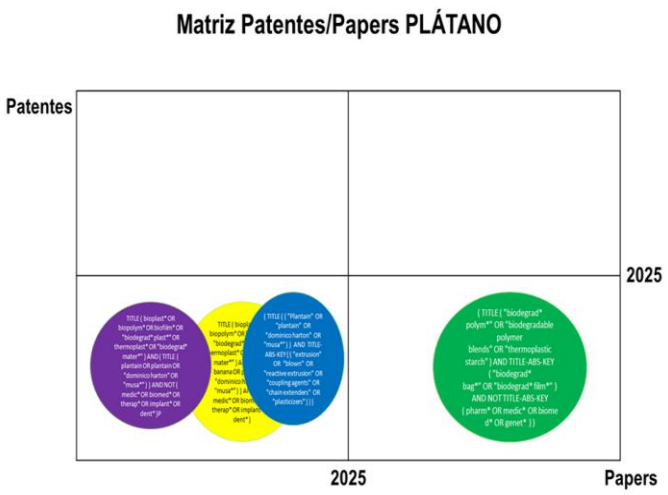

Figure IV. Matrix Patent-Papers plantain agroindustrial chain. Own elaboration

Continuously through the use of the Hype cycle methodology, based on the initial model of [36] it is pointed out that every emerging technology behaves as a five-phase cycle according to the life cycle and reflecting its evolution. It begins with innovation, marked by potential technological breakthroughs, although in many cases there are still no utility products and commercial viability remains uncertain. The second phase is the heyday of inflated expectations, where the initial hype generates a series of notable successes and some failures. Continuing into phase 3, you enter the disillusionment stage, where interest wanes as applications and experiments fail, and you identify that investment continues only if the surviving vendors improve their products to satisfy early adopters. According to the above, Figure V and VI present the results of the application of this methodology.

- Emerging technologies from social networks. Hype cycle Biofilms:

Figure V. Hype Cycle biofilms for analysis of emerging technologies from social networks. Own elaboration.

The opportunities for Plantain prototypes are detailed in the table II, which have been evaluated through various technological analysis tools, including their progression in the S-curves, their mapping within the patent-papers matrix, and their position and trajectory in the Hype Cycle. In addition, key opportunities for their future development are identified, based on the comparative analysis of these methodologies.

This integrated approach allows a visualization of the technological adoption phases, the degree of maturity and the innovation potential presented by the prototypes, providing a solid basis for the design of implementation and commercialization strategies in the context of their technological evolution. The table also facilitates a more detailed evaluation of the interaction between the different metrics and their implication in the identification of opportunities for improvement and expansion in the field of technological development in the agroindustry.

Table II Resultados/oportunidades en productos de plátano

Methodology	Results/opportunities in Plantain products
S Curves	Decision-making in accordance with the position in the technology life cycle, related to the appropriate time to exercise technological rights and intellectual property mechanisms, monitoring/surveillance, investment strategies.
Patent-Papers matrix	In the consolidated critical monitoring factors in the two prototypes, Plantain products are located in the lower right quadrant, with a turning point for future papers, which shows opportunities in internal R&D, external R&D, cooperative R&D, publications, in the topics located in said quadrant: biodegradable polymer blends, thermoplastic starch, and biodegradable film
Hypecyle	Opportunities in 15 emergency components in biofilms, including: juice packaging, tea bags, paper, clothing, shoes, filters. Opportunities in 12 emergency components in gluten-free pasta, including: gluten-free flours, noodles.

Own elaboration. Based on the plantain agro-industrial opportunities.

- Emerging technologies - from social networks. Hype cycle for prototype pasta (gluten-free):

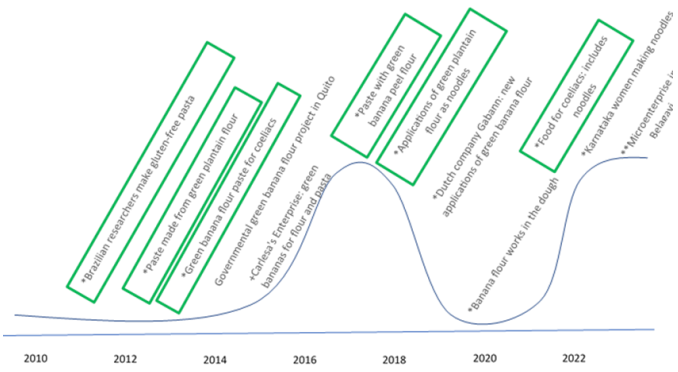

Figure VI. Hype Cycle prototype pasta (gluten-free) - analysis of emerging technologies from social networks. Own elaboration.

V. DISCUSSION

Analysis from S-curves and Hype Cycle

As an initial phase with the aforementioned CFSs, the search equations and their respective inflection points were obtained. The use of the Sigmaplot software free version, provided the analysis of scientific data, statistics, and generation of graphs, counting on a series of established models and allowing the introduction of new models to perform the adjustment of the sigmoid or S-curve curves obtained [18], such methodology was previously tested demonstrating optimal results according to the study of [13] on the "Application of technological intelligence tools" and additionally the study "S-curve analysis and technology life cycle [34]

In this case, it was observed that the equations analyzed for patents generated consolidated inflection points that are in the range of years between 2009 and 2024, according to these results, it can be deduced that technologies generate reliability. In the same way, it is relevant to consider the continuity of the application of legal mechanisms related to intellectual property and technology, based on the scope of investment strategies, reflecting and suggesting the relevance of a detailed analysis at the time of investing, due to the inflection point recorded in the past. However, these strategies require exploration in terms of other technological indicators, such as efficiency, technological products, and the success of innovations resulting from the technology.

In terms of investment strategies, selective monitoring, and investment [35] are recommended, bearing in mind that this type of technology with inflection points in the future, represents a significant opportunity for the continuity of publication and construction of projects and research, thus generating new technological development products. At the same time, the status and technologies found in the present study generate reliability to the observers in direct correlation with the CFSs highlighted by the experts and the result of the diagnosis of the technologies yielded in the different research phases. In terms of investment strategies, selective monitoring, and investment [35] are recommended, bearing in mind that this type of technology with inflection points in the future, represents a significant opportunity for the continuity of publication and construction of projects and research, thus generating new technological development products. At the same time, the status and technologies found in the present study generate reliability to the observers in direct correlation with the CFSs highlighted by the experts and the result of the diagnosis of the technologies yielded in the different research phases.

Regarding the Patent-Papers matrix. This is interpreted through the reading of the four quadrants, where the X axis represents the inflection point for papers, and the Y axis represents the inflection point for patents. This has facilitated the strategic alignment of the research with the innovation objectives previously established by the participating organizations or associations, providing a broader perspective that contributes to future decision-making. This perspective from the associations, with the data obtained in the Hype Cycle for the analysis of emerging technologies, evidences an expectation and shows us a result close to that obtained in the study focusing on the different TT methodologies developed in this paper. We can observe that different technologies, such as the development of biopolymers, biodegradable packaging or containers, and various applications for plantain-based flours such as the production of pasta, resemble the information obtained through the Hype cycle elaborated for social networks and worldwide trends, illustrated in the Hype cycle Biofilms (Figure V) and for the gluten-free pasta prototype (Figure VI).

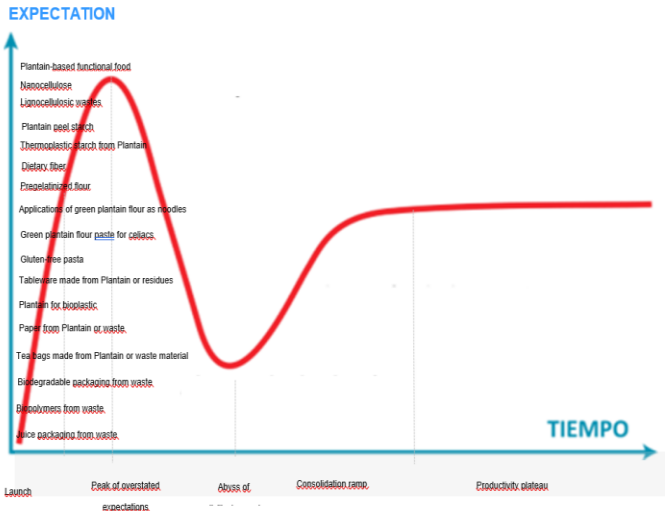

Figure VII. Hype cycle - for analysis of emerging technologies - from partnerships. Own elaboration.

In the cycle of over-expectation from the associations illustrated, there is evidence of a framed mention of by-products and residues such as plantain peel and fiber from plantains, common to that reported by [37]; [38] who refer that the most widely used and researched by-products worldwide are plantain peel and fiber/Plantain. These have been waste materials with little or no use for many years, but there has been an increase in research on the analysis of their properties worldwide, seeking to mitigate the generation of waste and thus reduce environmental problems.

Emerging technologies, innovations, and fields of knowledge

In the systematic review of the literature, the calculations of the emerging indicators were obtained using VantagePoint software version 15.1, identifying the main attributes associated with technological emergence, which refers to a technology that is still at an early stage of development and is expected to benefit various sectors of the economy and society generating various economic benefits in the coming years. Recognizing that emerging technologies are characterized by novelty and rapid growth, this study identified three key aspects related to emerging technologies: the countries that are leading their development (Figure VIII), and the technologies themselves, along with the main authors who are contributing to the field (Figure IX).

China, Thailand, and India were identified as ample producers [39], are leading research countries, with a particular focus on migration to sustainable and safe markets [40]. In the American continent countries such as Brazil (second worldwide), Mexico, the United States, Colombia, and Ecuador are countries with constant and growing research reports focused on the topic which, focused on the annual increase of publications, reports a peak of studies that are trending and increasing considerably since 2018.

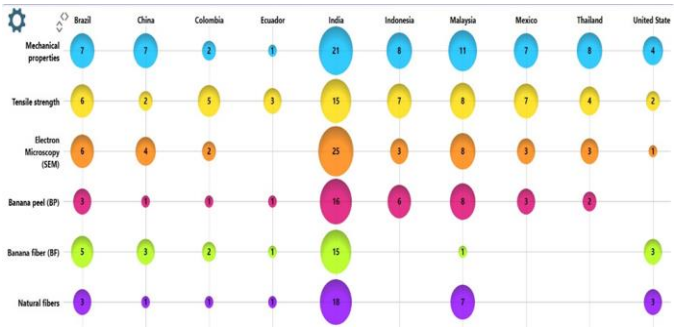

Figure VIII. Thematic vs Geography. Obtained using VantagePoint.

On the one hand, various studies found on both Musa spp. and cassava and corn starches [41], have observed that the use of these materials has generated significant advances in a variety of fields, which could be influenced and exploited by their biodegradability, availability in renewable sources, low cost, recyclability, natural lightness, and outstanding mechanical properties [42]; [43]. Some of these fields are biodegradable packaging [44]; [45], bioplastic materials [46], biomedicine [47], food sector catering products and single-use packaging are reported [48]; [49], in the industrial and textile sector they have developed biodegradable toys, textile garments and bags [50]; [51], among others. In this particular case, microfibers and nanoparticles are reported to be of special interest to some actors, stating that they can be used as enhancers of edible films and biodegradable packaging [52]; [53], thus, one of the big differences between the plastic currently manufactured and the one produced based on biopolymers, besides being environmentally friendly and sustainable, is that biodegradable polymers could be completely biodegradable and non-toxic, bearing in mind that upon degradation they can even be used as composting material and finally fertilizer for crops [43]; [54].

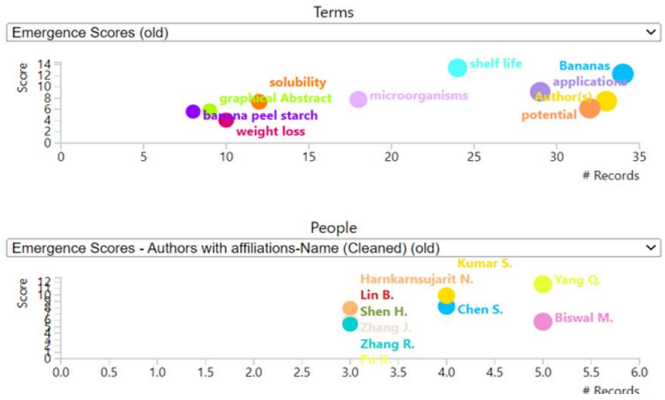

Figure IX. Emergence report. Obtained using VantagePoint

Similarly, according to the findings of the articles and patents tracked and broken down with the analysis of the emergency components obtained, it was observed that authors in Brazil Ecuador Holland, and India are pioneers in research and evaluations within the framework of the development of new products reinforced with plantain fiber [55], as well as of pastes and flours from plantain [56]; [57]. As reported by [58] this type of innovation is ideal for people with celiac disease, and in recent years it has again become a worldwide trend.

Finally, and trying to find other similar studies in the plantain chain, two recent studies on the plantain agro-industrial chain have dealt with issues of technology and scenario prioritization [59] and innovation management model for the same sector [60], the results of our study compared with the papers on foresight and Delphi had coincidence in 3 of the 62 priority topics reported in [59], these were: Gluten substitute, Preparation of biodegradable films from plantain and Biodegradable packaging, this means that the new foresight studies to 2035 continue to prioritize the topics and technologies analyzed in our project in the S curves, Hype Cycle and Patent Matrix Papers, on the other hand, compared to the innovation model study [60], the latter focused on prioritization of variables, diagnostic questions and prioritization of innovation models for the chain, although it is a study more focused on management and sustainability variables, it mentions the topics biodegradable packaging and production of biodegradable films from plantain as priorities for alignment with the innovation management model of the chain, which coincides with one of the focuses of our study related to biodegradable films and bioplastic.

Other studies on agro-industrial chains have applied S-curves and inflection point calculations [61], [62] but did not apply the Hype cycle or patent papers matrix. There are also several prospective studies in agro-industrial sectors, among which [63] and [64] stand out, but they do not make any application of the technological management techniques used in this research.

VI. CONCLUSIONS

Technology and innovation management techniques such as S curve, Patent-Papers Matrix, and Hype Cycle provide a solid framework for multidisciplinary collaboration between research and development teams which favors the creation of integrated solutions adapted to market needs, becoming a viable tool for the development of agro-industrial prototypes, facilitating a deeper understanding of the life cycle of the prototypes to be developed, from the innovation stage to the evaluation of their commercial viability. This strategic management allows us to identify opportunities for improvement and optimization at each stage of development, ensuring that prototypes are aligned with market demands and emerging technology trends.

Related to the life cycle analysis by S curves, the topics related to Bioplastic; Biopolymer; Extrusion; Blown; Reactive extrusion; Coupling agents; Chain extenders; Plasticizers in papers and patents are in the maturity phase with opportunities for investment and cost strategies, while the topics related to biodegradable polymer blends, thermoplastic starch and biodegradable film, from the patent point of view, are before the inflection point between the emerging, entering or key phases, that is, with technological opportunities due to high or pending growth rates in patents.

The use of plantain by-products for the development of new products represents an opportunity to diversify the commercial activities of companies and generate additional income for producers. This practice, not only contributes to the economic sustainability of the plantain value chain but also presents significant environmental benefits by reducing resource waste and mitigating the environmental impact associated with the disposal of these by-products. Given the social and food security importance of plantains, their integral utilization aligns perfectly with the objectives of promoting sustainable agriculture and ensuring the availability of nutritious food for local and global communities. Therefore, the application of technological management methods and techniques for the development of prototypes is not only a desirable option, but also an urgent necessity in the search for a more equitable, efficient, and sustainable rural and entrepreneurial development.

The techniques applied in the study for the analysis of emergence show a great opportunity for alignment between the emergency component of the Vantage Point software with the Hype Cycle and the patent-papers matrix. The Hype Cycle provides specific emergency elements that can be taken into account in the development of new prototypes and innovative products, and the patent papers matrix shows in a novel way those technologies, innovations or fields of knowledge in quadrants with future inflection points in terms of papers and patents, which can be used for decision-making regarding patenting and research and development dynamics.

VII. LIMITATIONS AND POSSIBLE LINES OF RESEARCH

The calculations of inflection points based on papers and patents are dynamic, so they must be adjusted over time since the conclusion about the life cycle or stage of the technology can change. It is recommended to use the same search equation in Scopus or similar equations in case of using different databases for patents, such as in the case of World Intellectual Property Organization (WIPO), patent inspiration or Free patents online.

Hype Cycle calculations based on Google news should be verified to ensure that each news item analyzed in order of importance is directly related to the technology or topic studied.

For future projects, it is recommended to automate the calculation of inflection points and the generation of the patent-papers matrix to optimize calculations and generate data and conclusions in real time. Currently, applying 13 nonlinear regression models to each time series becomes laborious.

The patent-papers matrix could be u sed to analyze technologies, innovations, and fields of knowledge in a country, cluster, or organization to map and establish quadrants for investment or prioritization in decision-making regarding projects, doctoral thesis topics, technology transfer, and technology procurement, among other aspects.

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