A MODEL FOR A BIOTECHNOLOGICAL ENTERPRISE BASED ON SUSTAINABILITY AND THE CIRCULAR ECONOMY: AN APPROACH BASED ON MEXICAN INNOVATIONS

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ABSTRACT

Sustainability is a differentiating factor for businesses and is particularly relevant in businesses that include an element of biotechnology. The current work presents six cases involving Mexican companies, which arose from biotechnology innovation projects with a focus on sustainability. The methodology used in this work is content analysis, applied to the texts and reports of businesses having this type of profile in order to discover similarities and establish relationships. These examples may serve as a foundation for providing new opportunities for biotechnological and sustainable enterprises.

Keywords: Enterprise, Biotechnology, Sustainability.

INTRODUCTION

In a world where qualities such as competitiveness and innovation are determining factors for developing national and organizational economies, advances in science and its potential contribution to engineering is foundational for the creation of new products. However, the technological enterprise must establish new patterns of production, since otherwise; it will continue to imitate linear models that prove to be unsustainable in the long term. Therefore, a biotechnological innovation that is focused on sustainability may be a crucial element in the generation of entrepreneurial opportunities (Petruzzelli & Rotolo, 2015).

This article uses content analysis method to study the reports from six cases of innovative Mexican enterprises that are based on biotechnology with the aim of demonstrating how this type of business is one path towards sustainability. In order to achieve this, an approach is made towards sustainability, the circular economy and partnership with the companies involved in the process, with the aim of providing an example of the way in which new business models are also related to biotechnology innovation. Moreover, the text seeks to explain the role of biotechnology innovation in the generation of products that are innovative and sustainable. In the methodology section of this article, an analysis is made of the six enterprises that are based on biotechnology, in order to serve as a framework for presenting a model that seeks to systematize the process that this type of company usually follows. The last section of the article presents conclusions that argue in favour of biotechnological enterprise with an emphasis on sustainability and the circular economy.

THEORETICAL FRAMEWORK

Sustainability and Technology Companies

The current agenda of international cooperation organizations considers the implementation of policies and practices in favour of environmental protection to be a priority. This effort includes the business sector's incorporation of practices that favour the environment, especially by those companies whose focus is technology. International discussion recognizes the part played by businesses in environmental protection agreements and in the potential for achieving sustainable development (Guapatín, 2003).

Historically, the business sector has exploited natural resources in order to generate wealth; however, such unregulated activity in nature has endangered the delicate equilibrium necessary for human survival (Hurtado et al., 2016). Given the present and future ecological challenges, businesses from both the production and service sectors must accordingly take on their corresponding responsibility and for this, a paradigm shift is an absolute necessity (Secretaría de Economía, 2009).

Understanding this necessary paradigm shift involves reconsidering the manner in which a business has traditionally been connected with its surroundings. The Business-Nature relationship has been formulated according to various paradigms (Heredia-Escorza et al., 2011). The first of these is that of the provider; in other words, the business may take indiscriminately from nature whatever it needs in order to survive and grow, without any concern for the natural environment. A second paradigm is that of conquest, according to which the business seeks to dominate nature. The business sees itself as being above the natural environment, in a dominant position over nature. As a result of these two prevailing paradigms, businesses have brought about drastic changes in the environment and have substantially altered their ecosystems. A third paradigm involves the perception of the environment as a home in which we must live and for whose care the business must assume responsibility. There is also a fourth paradigm, of a bio centric relationship, which views nature as something into which the business is integrated and not separated from. To use a metaphor, the business is but one thread that forms the entire network of nature, meaning that whatever it does to the environment, it is ultimately doing to itself. A business that functions according to the bio centric paradigm respects the biological system and the components that govern this relationship, attempting to integrate its business activity in a way that is harmonious with nature. This paradigm forms a strong link with the concept of the circular economy (Madero & Zárate, 2016).

According to this line of reasoning, the business, as an Institution, has the joint responsibility of innovating and/or incorporating entrepreneurial processes in order to reduce, eliminate and/or recover any negative effects on the environment that its industrial activity has generated. As will be shown below, biological innovation and entrepreneurship play an important part with regard to this last point.

In accordance with this paradigm shift, the UN in its Objectives for Sustainable Development, especially numbers 9 and 12, has presented the need for industries to change their paradigms for exploitation of resources in order to both promote inclusive industrialisation and foment innovation for sustainable production and consumption (PNUD, 2016). According to Scheel (2018), these proposals are a response to the urgent need that exists for production and consumption chains to achieve a systemic focus that is motivated by the circular economic model. In this regard, a sustainable biotechnological enterprise may be considered one innovative resource

for the circular economy, since using biotechnology industrial waste may be recycled in order to create new innovative producers, as will be shown below (Ono, 1991).

In summary, it is clear that most organizations, for international cooperation, are driving forward the idea of change in current business practices in favour of the environment. Within this context, innovative enterprises have an important role to play, generating business models that are both innovative and sustainable and which deliver products in such a manner as to minimize aggressive practices against the environment. Another component of this general tendency is the range of possibilities offered by biotechnology, which is explained in the present article. The challenge is to promote a balanced, sustainable model in which the business sector shifts its paradigm to a new integrated model that might sustain over time and remain in place as a result of cooperation between the various agents involved (Sepulveda & Gutiérrez, 2016).

The Importance of a Circular Economic Model

A company that is committed to being sustainable must be guided by a circular economic model in order to truly achieve its goal. The circular economy is an intentionally restorative or regenerative system by design, which seeks to redesign products, business models and production patterns in such a manner as to systematically eliminate all waste products. The circular economy constitutes a new economic model based on the environmental economy that minimizes its impact on externalities (Raufflet et al., 2017).

The goal of the circular economy is to disengage global economic development from the consumption of finite resources by minimizing the use of virgin resources, reusing already existing resources and adopting clean technologies. In essence, the circular economy revolves around the idea of a circular flow of resources, materials and energy that results in low exploitation of resources, high usage from materials and products, low energy consumption and the elimination of pollutant waste products (Lett, 2014). This is achieved through replacing the concept of life cycle end with a closed loop, integrating the concept of circularity into the inclusive loop system, which has a great impact on each of the three subsystems of the biosphere (Volpentesta, 2016).

The circular economy is based on three key principles and each deal with various challenges faced by industrial economies with reference to resources and system integration (Raufflet et al., 2017).

Principle 1: To preserve and improve natural capital by maintaining strict control of finite resources and balancing the flow of renewable resources.
Principle 2: To optimize the use of resources by rotating products, components and materials so as to achieve maximum utility at every point of both the technical and biological cycles.
Principle 3: Foment system efficacy by discovering and eliminating negative externalities.

The yearly sum of environmental services totals approximately 33 billion dollars, demonstrating that the circular economy has been growing stronger over the last several years. Thus, it is shown to be not only a form of addressing environmental deterioration but also a viable business opportunity for industries (Chicaiza, 2011). It has been estimated that if the manufacturing sector alone were to adopt this business model, it would save approximately 680,000 dollars (CE100, 2017).

The Circular Economy 100 platform has shown that the circular economy is not only a theoretical conception of reality to which businesses may contribute but also a practical model that is already being used by more than 90 multinational firms, including Renault, Philips, Coca-Cola, Unilever, Cisco and Apple (CE100, 2017). It should be noted that although the circular economy

Can bring clear advantages to any business, businesses that enjoy the greatest benefits are usually those that have the largest stake in technological innovation and can adopt the model in a more comprehensive manner (Korhonen et al., 2018).

This last point is what has given rise to multiple innovation projects seeking to apply the principles of the circular economy to the creation of products, making the greatest use possible of the capacity to reuse waste products of certain industries for the creation of new products in others (Peñaherrera & Cobos, 2012). Examples include proposals such as those of Fonebank, which buys and resells cellular telephones, MudJeans, which rents jeans made from ecological cotton and Umicore, which extracts the precious materials found in technological devices (CE100, 2017). Although the circular economy might be seen as a great challenge for new industries, it is actually a truly worthwhile proposal (Huang, 2011). As the current article proposes, the circular economy may have a greater possibility of materializing if new opportunities are made available as a result of biotechnology.

Biotechnological Innovation for Sustainability

Innovation is a key condition for both businesses and countries to achieve economic progress and competitiveness and will become the new criteria for evaluating progress among countries. Moreover, innovation is foundational for economic growth, sustainability and use of resources and environmental improvement (Freeman and Soete, 2000). However, Latin America currently suffers from a gap in innovation (Cimoli et al., 2009; Paus, 2014). There is a lack of clear scientific policy for the development of new sectors which focus on technology (Cimoli et al., 2009). According to Villasana-Campos et al. (2018), the field of scientific-technological innovation is gaining ground in Latin America, although its progress still needs to be substantially increased. Innovation is needed in order to increase productivity, incorporate advanced technology in the production sector and achieve sustained rates of growth (Foxley & Stallings, 2016). Even though innovation in Latin America is in its initial stages, it is already transforming the way in which companies operate, as well as creating new opportunities in terms of products and services. Although innovation is a strategic consideration for all companies, this does not mean that it has the same influence and impact on all organizational sizes (Naranjo-Valencia & Calderón-Hernández, 2015). As will be shown in this article, new innovative enterprises with a biotechnology base are discovering possibilities for sustainable business models that are based on a circular economy.

Regarding innovation and its relationship to competitiveness during the last few decades, businesses have demonstrated a keen interest in acquiring competitive advantages that allow them to achieve sustainable economic growth. According to the Cross-sectional Committee for Innovation (CII-original Comité Intersectorial para la Innovación), one of the methods utilized by companies most frequently in order to acquire competitive advantages is the development of a greater capacity to innovate, that is, to "*generate new products, designs, processes, services, methods or organizations or else increase their current value*" (CII, 2011).

It is understood that a business that is stronger in the area of innovation will have more opportunities for increasing its productivity and sales, since they will have at their disposal tools for increasing competitiveness, both internally and on the regional level (Charreau, 2001). Accordingly, competitiveness and innovation have been closely tied during the last decade. Thus, innovation is seen to be one of the most important investments for businesses.

According to the Global Competitiveness Report (WEF, 2014), innovation cannot generate benefits unless strong investments are made. In order to achieve more innovation, a greater investment in research and development (R&D) is necessary.

Regarding this, Montoya (2004) argues that scientific and technological innovation is the instrument that can allow businesses to be developed and strengthened since it opens them up to new business opportunities. Although this initially appears to be a factor that gives rise to inequality regarding the possibility of innovation, new opportunities may be created using public funds in conjunction with Universities and Research Centres, for the purpose of innovation in the area of more sustainable products or services (Geroski, 1989). This type of enterprise (in this case, biotechnological) can promote sustainability and the circular economy in the industry (Santana, 2017).

Sustainable innovation is a process that is geared towards discovering new ways of achieving the greatest production or greatest value using the same amount or fewer resources, that is, to improve innovation processes (Decarolis & Deeds, 1999). In this manner, entrepreneurs, driven by new business models based on circular economies and aided by biotechnology, may have the opportunity to innovate in the creation of sustainable projects (Manninen et al., 2018). On the other hand, part of these innovation processes must be able to count on legal protection via the issue of patents for the exploitation of the inventions, as will be shown below. In this regard, Arredondo-Trapero et al. (2016), in their study encompassing several Latin American countries, discovered that the application of patents is a differentiating factor for international competitiveness with reference to innovation. Although not all patents studied involved biotechnology, this field of science is certainly represented in part of them.

Biotechnological industries seek to develop opportunities for the use of living organisms or compounds obtained from living organisms in order to develop products that are valuable for human use (Knockaert et al., 2015). Although biotechnology has been used since the dawn of history in activities such as making bread or alcoholic beverages, modern industry has incorporated a greater variety of its elements and included aspects ranging from cellular and molecular biology to the use of microorganisms for improving production processes. Thus, biotechnology, in addition to other areas of bioengineering, is closely tied to improvement in areas such as agriculture, energy, chemical and pharmaceutical industries and the management of waste products and residues (Shan et al., 1994).

In contrast to past applications that were limited to the generation of new products, one of the current challenges facing the biotechnology industry is the improvement of existing products, with a focus on increasing their production efficiency, in addition to strengthening their capacity to confront global changes (Tripurasundari, 2018). Thus, biotechnology has found several points of contact with businesses and the industry, providing new circular economic models using technological innovations for making the most use of resources, both before they are sold and after they have been used (Fan & Song, 2017). In this way, the current requirements of the industry have become a challenge for engineering, making it necessary for them to think in terms of new production processes that are both sustainable and responsible and which consider the entire lifecycle of the product and not merely its value cycle (Farid et al., 2017).

MATERIALS AND METHODS

The six enterprises were selected from the biotechnological innovation reports of the Monterrey Institute of Technology (Tecnológico de Monterrey), both on its website and in its Institutional journals, as well as from forums and interviews with the entrepreneurs. The research was carried out in this same institution, due to the biotechnological infrastructure it has developed for generating research projects in this area, with the expectation that these projects would later grow into enterprises.

Method

According to UMSL (2016), content analysis is a research tool used to identify the presence of specific words or concepts within texts or groups of texts. *"The researchers quantify and analyse the presence, meaning and relationships of such words and concepts and subsequently make inferences concerning the messages contained in the texts"* (p.1). The reports from the six cases involving biotechnology-based enterprises were examined in order to analyse the characteristics that identify these companies as being geared towards the circular economy. According to UMSL (2016), a relational analysis (a type of content analysis) "*begins with identifying the concepts present in a given text or group of texts. However, a relational analysis goes beyond their mere presence to explore the relationships between the identified concepts*" (p.1). The application of this technique made possible the identification of the various criteria for selecting this type of enterprise. The cases for the enterprises were filtered based on the following keywords: biotechnology company, patent, innovation and industrial waste.

Biofase

Biofase is a company located in Nuevo León; this company produces bioplastics from avocado seeds. It arose in 2014 with sponsorship from the Banamex Economic Award (Premio de Economía de Banamex) for the sustainable business of the year as an entrepreneurial project of Scott Munguía, its current president and founder. Biofase owns a technological patent that allows it to be one of the few businesses in Mexico that produces bioplastics, a product that previously had to be imported into Mexico. Its activity has expanded to include 11 countries in Latin America. This has allowed it to take on an important leadership role in the production of biodegradable plastic in the region and thus make a contribution towards sustainability.

Technology is the most important differentiating factor for Biofase. It is a company with a global presence that produces bioplastics from non-food products and uses agricultural by-products as raw material. Biofase's technology is considered to be one of the five most important innovations on the global level in the bioplastics industry. Its competitive advantages are based on the following diverse factors: price, since similar imported products are at least twice as expensive as those produced by the company; delivery time, since it is produced in Mexico which results in faster delivery; purchasing volume, since it admits very small purchases; quality assurance, since it delivers personalized customer assistance and finally, environmental impact, since it manufactures a biodegradable product from agricultural by-products.

The biodegradable resins generated by Biofase may be processed using all conventional plastic moulding processes. They replace certain applications of polyethylene, polypropylene and polystyrene. They are ideal for plastic processing companies that wish to develop new business units which are geared towards sustainability (Biofase sustainable plastic, 2018). The

case of Biofase is an example of innovative biotechnological entrepreneurship. As a result of biotechnology, this company focuses on making use of industrial waste products for generating innovative products. For these reasons, based on the data collected from this company, it has been categorized as a biotechnological company that exhibits a business model which is focussed on sustainability and the circular economy.

BioSolutions

BioSolutions is a company that develops and produces bioplastic compounds from natural fibres by reusing secondary products from the agave industry. The company makes use of the fibres from agave bagasse, which is considered a waste product by the tequila and honey industries, along with other secondary agricultural products from the region. The company has received recognition, having won various national and international entrepreneurship and innovation awards for being a company that provides sustainable alternatives for the plastic products industry. This company has been on the market for more than five years and owns a patent that provides the plastics industry a bio-based and sustainable alternative for products and packaging. BioSolutions' bioplastics compounds serve as a sustainable alternative to traditional plastics. Their products exhibit the same performance as conventional plastic but possess the advantage of reducing the carbon footprint of the products and companies that consume them. BioSolutions offers three main advantages to its clients: innovation in the use of materials in order to differentiate sub-products with a sustainable texture and appearance; attractiveness for markets that require the products that they consume to be sustainable and finally, a decrease in the company's carbon footprint by decreasing CO_2 emissions into the environment.

Agave fibre, when used as a bioplastic product, contributes useful mechanical properties to the product and reduces its weight while at the same time substituting part of the plastic with a renewable source. Biosolutions emphasizes that the bioplastics produced by them are durable, bio-based materials based on renewable cellulose sources. The company does not manufacture biodegradable materials since their intended use is in durable market goods and reusable products. The company favours recycling, thus supporting the Circular Economy and real sustainability of the materials (BioSolutions natural fibre of plastics, 2018). The case of BioSolutions also presents an innovative enterprise. This company, whose existence is made possible by biotechnology, focuses on making use of industrial waste materials in order to create innovative products. It is for this reason that the characteristics exhibited by this innovative company characterise it as a biotechnological enterprise that is based on sustainability and the circular economy.

Geco

Giselle Mendoza, an economics student at the Monterrey Institute of Technology, undertook a business project aiming to produce biomaterials from the peel and bagasse of oranges. The idea arose from the need to find a biomaterial that could replace conventional plastic. With the aid of biotechnology researchers, she was able to create a material that serves as raw material for the production of disposable cups. Mexico is the fifth largest producer of oranges in the world and according to Giselle Mendoza, only 45% to 60% of the fruit is exploited by the industry, while the waste products produced might cause health problems since, in large quantities, they generate gases that may cause respiratory infections in areas near where they are processed. Although part of this material is used as compost, the remaining material releases gases that cause respiratory illness. The biopolymer is flexible and transparent, making it ideal for bottling and packaging. It

can also be produced in the form of a protective resin for use with books. Furthermore, it has a potential biomedical application, since it can be utilised to heal burn injuries. It can be used for treating injuries and burns instead of synthetic materials that cause discomfort to the injured patients (Plastec U.S.A., 2017).

The product seeks to replace petroleum-based products that negatively impact the planet. As a result of this innovation that Geco intends to industrialize, the company has been invited to business fairs in Europe and the United States. It has also been able to enter programs that offer Training in business models such as Innovation for Equality (2017), which selected 15 young people from Latin America and the United States. Giselle is part of the Leaders of Tomorrow program at the Monterrey Institute of Technology. She claims to have found in biotechnology a way to improve the country's economic and social situation. Giselle recently was awarded the Tech Woman Award (Premio Mujer Tec) in the category of Entrepreneurship. Her company, Geco, seeks to replicate the laboratory prototype on an industrial scale with a pilot plant. It will subsequently seek to form agreements with clients in order to begin production on an industrial level. The strategy it has been following is to create partnerships with plastic-producing businessmen (Santiago, 2017). According to the data presented by this company, it may be classified as a case of biotechnological entrepreneurship in which sustainability and the circular economy is at the centre of its business model.

ECOPlaso

Ecoplaso is a start-up created by four EXATEC Biotechnology Engineering students from the Monterrey Institute of Technology, Puebla Campus, who came together in order to create disposable plastic products such as cups and plates from bioplastics obtained from fruit and vegetable peels. The company currently focuses on developing fibres for textiles.

Biotechnology engineering graduates Barbara Arteaga, María Fernanda García, Claudia Coeto and Ana Cristina Cabrera began their start-up in the Center for Entrepreneurial Culture of the Monterrey Institute of Technology, thus beginning the journey of this young company. Currently, these graduates produce textile fibres, a material very similar to leather. As in the other cases, these are also made from an organic waste material, which is obtained through partnerships with various restaurants and coffee shops in Puebla.

The peels of fruits and vegetables are the main material used for their completely sustainable creations. They are currently seeking to form an agreement with the garbage collection system of the Puebla city council in order to procure more organic material for their production.

This project was chosen to represent Mexico in the Youth Organization Forum & Beijing Sister City Youth Camp 2014. It was also one of the 300 best projects of Clean Tech Challenge Mexico, as well as being among the 20 best possible projects of 2015. This enterprise won the Bi-National Green Energy Forum 2016 and was one of the 500 best socio-environmental projects, according to the Green Latin America Awards. Its greatest achievement was winning first place among 50 projects selected for the 2016 MIT Global Entrepreneurship Boot Camp.

The start-up plans to launch a line of vegan products, such as wallets, key rings, belts, purses and sandals, produced using the fibre it developed. In the future, it plans to export the textile to be used as a raw material in other industries, such as the shoe and furniture industries (Pontaza, 2017). The case of ECOplaso presents another innovative enterprise that uses biotechnology in order to utilize industrial waste material to generate innovative products. Possessing these characteristics, this biotechnological enterprise is based on sustainability and the circular economy.

Ezkatec

EZKATEC, LLC, is a biotechnology enterprise dedicated to investigation, development and elaboration of high-value nutritional products. EzkaTec focuses on utilizing whey, a waste product from the milk industry, by transforming it through an integrative process.
It must be noted that whey is highly exploitable, allowing it to be used very efficiently. The company seeks to standardize and innovate with whey sub-products.

The process consists in recovering proteins from the whey using an ultrafiltration process. The fraction that is rich in protein is thus recovered and subsequently lyophilised in order to obtain a sub-product in the form of a freeze-dried powder that is low in lactose. The filtered fraction is separated for use in obtaining probiotic biomass via fermentation. The biomass recovered by centrifugation is then lyophilised, resulting in a second high-value product obtained from the overall process. In this process, the whey used is supplied by a variety of companies.

The following are some of the products produced by the company:

Pro B-a powdered form of lyophilised *Lactobacillus casei* packaged in small envelopes for the nutritional supplement market and commercialized in both specialty shops and retail sales.

Prolact-a probiotic capsule developed from lyophilised *L. casei* and intended for the pharmaceutical market for therapeutic treatment of eating disorders or replenishment of intestinal microbiota after use of antibiotics or other drugs.

ProBvida-is a juice that does not require a cold chain and provides enough *L. casei* in order to achieve a lasting prebiotic effect.

The consumer base for both ProB and ProBvida is very large. Since they are prebiotics, the products possess the advantage of being consumed by people of any age and sex, without risk of complications or side effects. Prolact's target market is the pharmaceutical industry, especially the niche of specialty drugs for treating gastrointestinal disorders (Tecnologico de Monterrey, 2016). This case of entrepreneurship is yet another example in which biotechnology has made innovation possible, by allowing the waste material of one industry to be used for generating innovative products, thus achieving an orientation towards sustainability and the circular economy.

Global Nano Additives

Each year, more than 26 million tonnes of oil containing contaminants such as chlorates, sulphates and phosphates are released into the environment. In order to turn back these numbers and increase the efficiency of lubricating oils, Global Nano Additives is the first company to develop, produce and commercialize lubricant additives on the global scale that are based on nanotechnology and environmentally-friendly.

Global Nano Additives, IPC, is a spin-off of the Monterrey Institute of Technology that develops additives for use as lubricants at high pressures and temperatures in the metal cutting, rolling and forging industry. Its products are characterized by their low cost, sustainability, efficiency and for the fact that they do not generate toxic waste products. This company does not yet compete directly on the market (Tecnologico de Monterrey, 2016). This case of entrepreneurship is another illustration of how innovation made possible by biotechnology allows the waste material from one industry to be utilized to create innovative products for another industry, thus promoting sustainability and the circular economy.

RESULTS AND DISCUSSION

From the analysis of these six cases of entrepreneurship, whose success lies in their ability to make use of resources that are considered waste products by other companies or industries, the following model has been elaborated (Figure 1).

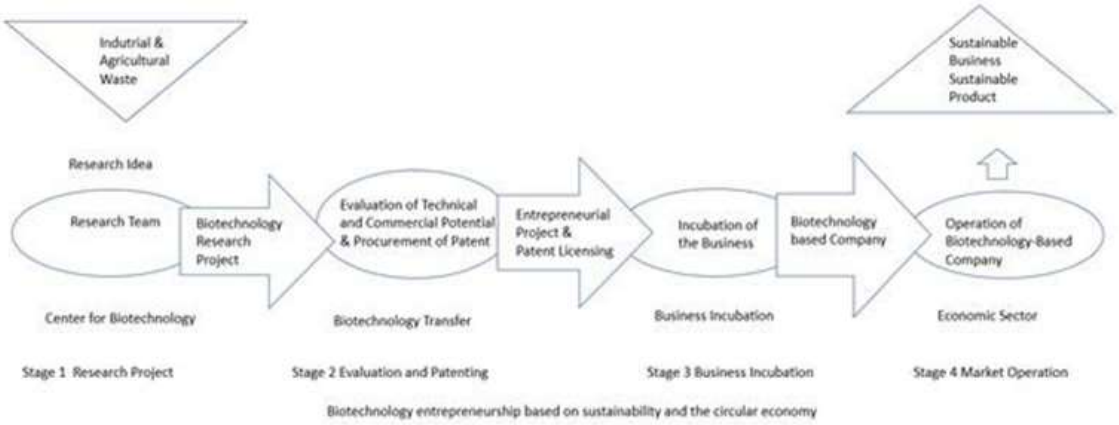

FIGURE 1
BIOTECHNOLOGY ENTREPRENEURSHIP BASED ON SUSTAINABILITY AND THE CIRCULAR ECONOMY

The model first presents stage 1, the research stage, in which the research team considers the possibility of working on a biotechnology project that makes use of industrial waste products. From the initial approach, the foundational idea is that of the circular economy with a focus on sustainability. This idea is formalized as a biotechnology research project, to which resources, technical infrastructure and a research team are allocated. The project is usually managed by a biotechnology investigation centre, which in the current case is a University.

The goal of the project is to investigate how the waste product may be processed for use in other applications. Once the investigation project has been concluded, it proceeds to stage 2-technical and commercial viability. Once its viability has been evaluated, a patent is sought. This patent provides legal protection in order to secure its exclusive use. If this patent is procured by the biotechnology investigation centre, the institution will grant a license to the entrepreneur by means of a contract. After licensing, the project proceeds to stage 3, whose goal is to incubate the entrepreneurial project until it may take on the form of a business that can venture into the market, guaranteeing partnerships with clients and providers, which is the goal of stage 4.

These cases present companies that have sought to create highly innovative products based on biotechnology. This model attempts to project a model for biotechnology entrepreneurship based on innovation and use of resources and adopting circular economy and sustainability models.

CONCLUSION

In conclusion, entrepreneurs have a significant area of opportunity in the creation of sustainable, innovative products based on biotechnology. This is made possible by close collaboration between the entrepreneur, who manages innovative and sustainable projects; the university, which invests in research and development; the public sector, which allocates support and incentive for this type of project, and the business sector, which forms associate or client

partnerships. By this means it is possible to work together to accomplish these sustainable innovations on an industrial scale (Castaños, 1994).

Although in most cases entrepreneurs have encountered limitations regarding their access to biotechnological innovation due to the high costs that are usually involved, it is necessary that agreements be reached across sectors in such a way as to make the most use of the funds allocated by the government and the infrastructure possessed by university research centres, thus generating new business models (Castillo, 2006). Therefore, the examples presented in this study demonstrate biotechnology enterprises that were able to mature to the point of becoming viable businesses capable of integration into the market and thus opening up possibilities for the circular economy. A limiting factor recognized by the authors of this article is the fact that only six Mexican companies were reviewed. However, despite this small number, due to the specific profile of the companies to be analysed, sufficient data was gathered for practical application in other biotechnology-based companies in order to operate in a sustainable manner based on the circular Economy.

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