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Biopolymers as Multiplatform Materials to Improve Quality of Life and Well-Being

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Abstract. Biopolymers are all the macromolecular materials formed in nature or produced using bio-monomers. Biopolymers are extremely diverse materials, which have unique properties. Unfortunately, the general cost of biopolymers production is about 25 % higher compared to similar materials from petrochemical sources. Therefore, scientists must continuously pursue the search for differentiated applications for these materials. These new applications, especially those with enhanced added value, are essential for extending the use of these unique materials. In this context, the Biopolymers & Sensors Lab. (LaBioS) of the Federal University of Rio de Janeiro has been operating since 2008 in research related to the production of biopolymers. LaBioS works on the chemical modification and the nanomodification of these biopolymers. These were the strategies found by the group to increase the added value of these systems, allowing their use in several applications that positively impact human well-being. Therefore, we dedicate this work to describing the state of the art in biopolymers via text mining study of the content produced on this great subject from the year 2008 to the year 2021. In addition, we present here short case studies developed by the team that currently composes LaBioS. These cases cover several areas, ranging from drug release, through environmental recovery, to food security.

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Биополимеры как многоплатформенные материалы для улучшения качества жизни и благополучия населения

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Аннотация. Биополимеры – это природные или созданные искусственно с использованием биомономеров макромолекулярные материалы. Биополимерные материалы чрезвычайно разнообразны и обладают уникальными свойствами. К сожалению, общая стоимость производства биополимеров примерно на 25 % выше стоимости аналогичных материалов из нефтехимических источников. Поэтому ученые должны постоянно продолжать поиск различных вариантов применения биополимерных материалов. Эти новые области применения, особенно позволяющие получить продукцию с более высокой добавленной стоимостью, необходимы для более широкого распространения данных уникальных материалов. В этом контексте лаборатория биополимеров и сенсоров (LaBioS) Федерального университета Рио-де-Жанейро с 2008 г. занимается исследованиями, связанными с производством биополимеров. Сотрудники LaBioS работают над химической модификацией и наномодификацией биополимеров. Эта стратегия, применяемая данной группой исследователей для увеличения добавленной стоимости полимерных продуктов, позволяет использовать их в ряде областей, способствующих повышению благополучия населения. Данная статья посвящена описанию современного состояния исследований в области биополимеров, основанному

на интеллектуальном анализе текстов статей, опубликованных по этой важной теме в период с 2008 по 2021 г. Мы представляем также краткую информацию о результатах исследований группы ученых, в настоящее время работающих в LaBioS, которые охватывают несколько областей – от получения лекарственных средств и технологий восстановления окружающей среды до обеспечения продовольственной безопасности.

Ключевые слова: анализ данных, статистический анализ, интеллектуальный анализ данных, биополимеры.

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Introduction

Polymers are materials that are widespread in our society (Souza et al., 2008). Due to their versatility, they increasingly replace traditional materials, such as metals and ceramics, in various applications (Ferreira et al., 2017; Grance et al., 2016). It is easy to identify a myriad of polymeric artifacts that surround us, leading to the realization that polymers will be increasingly present in every aspect of our lives, from our birth to our last moments on this planet. However, a side effect generated by polymers on a large scale is the immense amount of waste produced (Maranhão et al., 2018), whose persistence time in the environment, given the exceptional chemical stability of the polymers, is in the order of hundreds of years. In addition, obtaining conventional polymers is a polluting activity since most conventional monomers are obtained from a petrochemical source (Marques et al., 2016) via fractional distillation of oil. Thus, the use of materials from renewable sources should be increasingly encouraged (Marinho et al., 2018). These materials have the potential to maintain our lifestyle, but with an infinitely less environmental impact than what we currently produce.

Biopolymers (Péres et al., 2017) are polymers produced by living organisms or obtained from renewable sources (Buono et al., 2018; Fertahi et al., 2021; Jensen et al., 2016; Kanehashi et al., 2015; Khan et al., 2016; Roguszewska et al., 2020; Sotoudeh et al., 2021; Techawinyutham et al., 2019; Zubkiewicz et al., 2021). Among them, the ones commercially called «green polymers» are synthetic polymers obtained using monomers from renewable sources (Costa et al., 2017). This class of polymers allows the production of new artifact products that are highly beneficial to nature because they are biodegradable or, when they are not, because they can store carbon from CO_2 in the form of macrostructures of biological origin.

Despite the numerous advantages presented by biopolymers, the cost factor is still an

impediment to the large-scale use of these materials. In recent years, the emergence and improvement of several biotechnological routes have allowed the increasingly competitive production of several biopolymers, such as polyhydroxyalkanoates (PHAs) and many monomers, such as lactic, glycolic, and succinic acids, as well as the 1,4-butanediol (Satam et al., 2019). These new processes and the derived chemical species have significantly increased the availability of biopolymers for the most diverse markets, including the automotive, textile, and packaging sectors for quick disposal items (Babu et al., 2013). Increasing the value added by these materials must be a constant concern for the entire scientific community. In this context, the Biopolymers and Sensors Laboratory (LaBioS) of the Federal University of Rio de Janeiro has been seeking, since 2008, to boost the use of biopolymers by modifying their properties by chemical modification or by preparing nanocomposites.

The extension of the use of these materials in each of these areas is a driver for increasing the quality of life of human beings, helping to preserve our planet, and this is our research group's ultimate mission. Thus, this work provides an overview of the scientific work in biopolymers from 2008 to 2021. This information was collected at the Scopus base and mined using various free and open-source tools. In addition, this paper briefly presents some studies developed by the team that currently runs the LaBioS. Besides, the retrieved information allows us to foresee the perspectives referring to biopolymers in the near future.

Text mining methodology

Scientific articles containing the word biopolymer in the titles or abstracts were collected using the Scopus database. The Scopus search was restricted to the broad term biopolymer only among the articles published between 2008 and 2021. The used search key was: *TITLE-ABS-KEY (Biopolymer) AND (LIMIT-TO (DOCTYPE,»ar»)) AND (LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) ORLIMIT-TO(PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) ORLIMIT-TO(PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013) OR LIMIT-TO (PUBYEAR,2012) ORLIMIT-TO(PUBYEAR,2011) OR LIMIT-TO (PUBYEAR,2010) OR LIMIT-TO (PUBYEAR,2009) OR LIMIT-TO (PUBYEAR,2008))*. The results were gathered using Zotero 5.0.95 and finally saved in a single RIS file. The data of these articles were separated into (i) titles and (ii) abstracts. The tools were LibreOffice Calc and LibreOffice Writer (both version: 7.0.4.2 Build ID: dcf040e67528d9187c66b2379df5ea4407429775). The online Voyant Tools (Hetenyi et al., 2019; Miller, 2018) (https://voyant-tools.org/) was used in the text mining of the most relevant words in the texts, which were cleaned by removing all the numbers and editors' names from them. Then, the set conditions in the Voyant Tools were (a) Fixed term *biopolymer* and (b) minimum coverage of 5 %. The second Text Mining tool used was the VOSviewer (van Eck & Waltman, 2010) (https://www.vosviewer.com/), which allows obtaining the main clusters from the titles and abstracts. The last cleaning step is unnecessary for the VOSviewer analysis, and the raw RIS file was used as produced by Zotero. The set conditions used in VOSviewer were: (a) Create a map based on text data, (b) Read data from reference manage files (RIS), Fields from which terms will be extracted ((c) Title and abstracts separately and (d) ignore structures abstracts labels and (e) ignore copyright statements both turned on). The counting method was set to Binary (f). To the titles and abstracts, the minimum numbers of occurrences (g) were set to 50 and 500, respectively.

Results of text mining

The data mining variation focused on text analysis is named text mining (Abramo et al., 2019; Lehmann & Wohlrabe, 2017; Martín-Martín et al., 2018; Panagopoulos et al., 2017). Text mining allows the data extraction from text documents (Jeong et al., 2019; Ma et al., 2019; Robinson et al., 2019; Zhou et al., 2019), being a handy tool in areas as diverse as medicine, engineering, and customer service (Lucini et al., 2020; Pezzini, 2017; Sun et al., 2018). The chosen time span, between 2008 and 2021 (May 29), is the period in which the LaBioS has been working on the subject of biopolymers. Specifically about the term biopolymer, the scenario between the years 2008 and 2021 is complex because of the myriad of papers collected, which was equal to 18,277 scientific documents. Of course, these numbers can vary depending on the database used. According to the Voyant Tools (VT), the titles returned 256,702 total words and 18,212 unique word forms. In turn, the abstracts returned 3,416,625 total words and 57,689 unique word forms. These numbers make clear that the ordinary analysis of these data is humanly impossible.

Therefore, the analysis of this complex scenario demands the computer assistance offered by text mining tools. Then, the first approach was performed using the Wordcloud tool from Voyant Tools. The results are shown in Figure 1. Besides, the Titles and Abstracts corpus can be inspected through these links:

Titles: https://voyant-tools.org/?corpus=91168bf881a70c7a8fbf0d31fc2c640d&lang=en

Abstracts: https://voyant-tools.org/?corpus=4c21860a0981330a26179bb37eac123a&lang=en

Among the texts, the most frequent words in the titles are *biopolymer* (2969); *based* (2348); *chitosan* (2085); *properties* (1713); and *using* (1327). In turn, the most frequent words in the abstracts are *biopolymer* (13834); *properties* (11658); *using* (9980); *chitosan* (8992); and *study* (8440). Voyant Tools also allows the calculation of the correlations between the terms. In both titles and abstracts cases, the fixed term was *biopol**. Among the most cited words into Titles and Abstracts, only *based* (among titles) and *chitosan* (among abstracts) presented significant (95 % of probability) determination coefficients equal to 0.69 and 0.16, respectively. The R2 values are small in both cases, indicating that a different methodology must be performed, allowing further explanations. One possible way to deal with these data is subdividing them by years, as performed elsewhere (Gomes, 2021). This approach is advantageous to understanding how the concepts or keywords evolve during research time. On the other hand, understanding how data are correlated in a massive amount of information is crucial to see how the investigations are being conducted. Therefore, another tool, such as VOSviewer, should be used.

Fig. 2 shows the clustering maps from the studied titles and abstracts between 2008 and 2021, while Table 1 shows the top trending inside the five most relevant clusters in the Titles and Abstracts (data obtained from VOSviewer).

These clusters are created according to the probability or level at which the words are grouped together and indicate how each word is connected to its neighborhood. Among the Titles, the most relevant cluster allows inferring the relevant concerning polymer and blends based on lactic acid or PHAs. The next cluster focuses on using these materials in environmental recovery applications, mainly related to removing heavy metals from the water. In turn, the third cluster deals with the production of PHAs by biosynthesis. The next cluster mainly focuses on biopolymers in medicine, highlighting the terms scaffold, delivery system, and tissue engineering. Finally, the fifth cluster deals with the green synthesis of these biomaterials, highlighting catalyst and

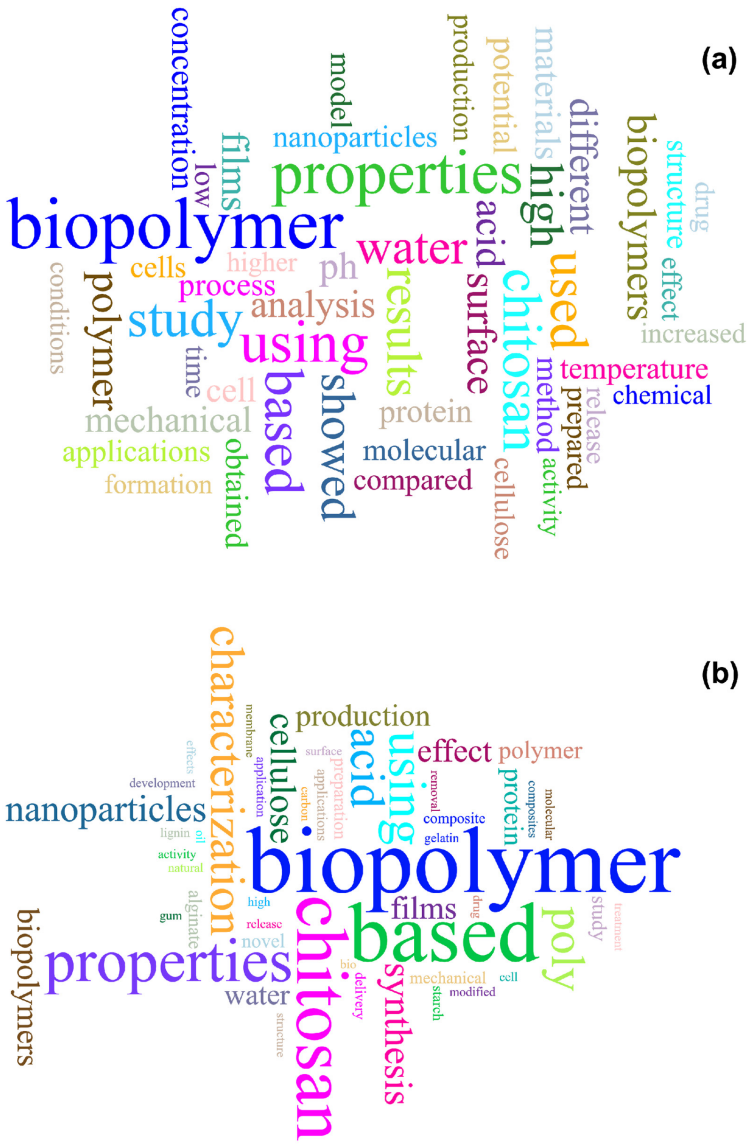

Fig. 1. Word clouds from studied titles (a) and abstracts (b) between 2008 and 2021

ionic liquid. In turn, among the Abstracts, the first cluster deals with the characterization of biopolymers used in environmental recovery applications. Among the top trending words, XRD (X-ray diffraction) and TGA (thermogravimetric analysis) are highlighted. The next cluster deals with medicine, and the highlighted words are drug, delivery, scaffold, and tissue engineering. The third cluster reveals the primary concern regarding the characterization of these materials, while the next one is focused on the preparation of biopolymers, evolving the terms gene, culture, glucose, and accumulation. Finally, the last cluster is probably concerned with silicon chemistry, which is relevant to the further developments in this field.

Therefore, data gathered from literature allowed inferring that relevant drivers in the biopolymers field focus on preparing and characterizing biomaterials useful to

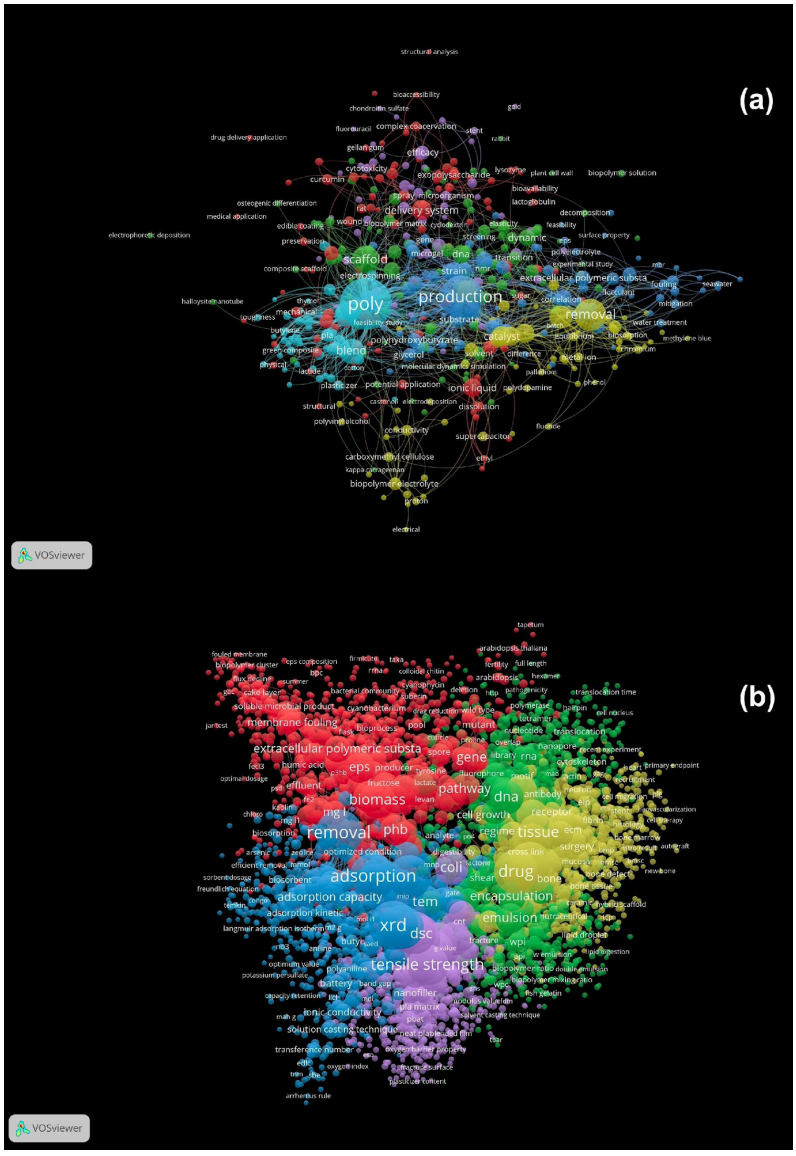

Fig. 2. Clustering maps from studied titles (a) and abstracts (b) between 2008 and 2021

environmental recovery and bio-medicine applications. In the contexts regarding biopolymer synthesis (Almeida et al., 2020; Araujo et al., 2015; Bedor et al., 2021; Costa et al., 2017; Daher Pereira et al., 2021; de Araújo Segura et al., 2018; Elias et al., 2021; Ferreira et al., 2012a, 2012b, 2015, 2017; Figueiredo et al., 2019; França et al., 2019; Gomes et al., 2018; Icart et al., 2018; Middea et al., 2017; Moraes et al., 2018a, 2018b; Neto et al., 2021; Pereira et al., 2013, 2014; Péres et al., 2014, 2017; Picciani et al., 2007; Ramon et al., 2018; Sá et al., 2017; Yusoff et al., 2021), environmental recovery (Aboelkheir et al., 2019a, 2019b; Bedor et al., 2020, 2021; Ferreira et al., 2012b; Figueiredo et al., 2019; Gomes et al., 2018; Grance et al., 2012; Nogueira et al., 2020; Si et al., 2020; Souza et al., 2012; Varela et al., 2012), medicine (Costa et al., 2018; Daher et al., 2021; Daher Pereira et al., 2021; Lange et al., 2016; Pereira et al., 2013, 2014; Ramon et al.,

Table 1. Top trending inside the five most relevant clusters obtained from VOSviewer

Cluster	Label in Titles	Occurrences	Label in Abstracts	Occurrences
1	poly	988	xrd	968
1	blend	236	removal	895
1	lactic acid	185	adsorption	872
1	hydroxybutyrate	145	x ray diffraction	782
1	hydroxybutyrate co	96	aqueous solution	761
1	hydroxyvalerate	77	ion	707
1	nanocomposite film	73	tga	600
2	removal	374	drug	787
2	aqueous solution	193	delivery	726
2	ion	139	scaffold	657
2	wastewater	130	tissue	589
2	sludge	111	vitro	555
2	dye	107	disease	417
2	extracellular polymeric substance	92	tissue engineering	398
3	production	684	thermal stability	721
3	strain	115	tensile strength	668
3	bacterium	110	nanocomposite	649
3	polyhydroxyalkanoate	105	blend	588
3	biosynthesis	94	pla	586
3	culture	92	dsc	538
3	substrate	92	elongation	484
4	scaffold	278	biomass	535
4	delivery system	144	gene	430
4	tissue engineering	90	g l	404
4	adhesion	75	pathway	404
4	efficacy	75	phb	380
4	tissue	56	culture	364
4	cancer	50	glucose	360
4	conjugate	50	accumulation	339
5	catalyst	146	dna	459
5	reaction	136	dynamic	382
5	ionic liquid	127	simulation	299
5	conversion	71	theory	269
5	solvent	59	regime	207
5	degree	50	deformation	189
5	green synthesis	50	regulation	184

2018; Sá et al., 2017; Souza et al., 2013; Vargas & Souza, 2011), and even nanotechnology (Araujo et al., 2015; Asthana et al., 2021; Costa & Souza, 2014; de Araújo Segura et al., 2018; Elias et al., 2015, 2016, 2021; Elkodous et al., 2019; Ferreira et al., 2014; Grance et al., 2012; Lopes et al.,

2018; Maranhão et al., 2021; Marques et al., 2016, 2017; Neto et al., 2018, 2021; Pal et al., 2019, 2021; Pereira et al., 2013; Péres et al., 2017; Pérez et al., 2020; Santos et al., 2021; Si et al., 2021; Siddaramaiah et al., 2012; Soares et al., 2017; Souza et al., 2007, 2009a, 2009b, 2010a, 2010b, 2012, 2013; V et al., 2020; Varela et al., 2013; Vargas & Souza, 2011) or Civil Engineering (Aboelkheir et al., 2018a, 2018b, 2021; Rocha Ferreira et al., 2020; Santos et al., 2018, 2021; Veloso de Carvalho et al., 2021) applications, LaBioS has presented several contributions in the last years, helping to boost and spread these relevant subjects. Thus, the following paragraphs are reserved for a brief description of some of the latest research activities under development at LaBioS and associated groups.

Case studies carried out in the LaBioS

Reduction of enzymatic browning of chunkey banana from the application of cassava biofilms by Sergio Thode

Between 2010 and 2019, the generation of solid municipal waste (MSW) in Brazil registered a considerable increase, going from 67 million to 79 million tons per year. In addition, per capita generation increased from 348 kg/year to 379 kg/year. However, the study of the gravimetric composition reveals that organic material remains the main component of MSW, constituting 45.3 %. On the other hand, dry recyclable waste totals 35 %, being mainly composed of plastics (16.8 %), paper and cardboard (10.4 %), in addition to glass (2.7 %) and metals (2.3 %), among others (Panorama dos Resíduos …, 2020). In Brazil, the banana (*Musa* spp.) stands out because it is the most widespread and because it is the most consumed by all social classes. Brazil is now the world's fourth-largest banana producer globally, with 6,953,747 tons per year (FAO…, 2018; https://www.embrapa.br/mandioca-e-fruticultura/cultivos/banana). Numerous initiatives are under development to minimize losses within this production chain, deserving highlight to the biodegradable packaging, also known as biofilms, from natural sources. These biofilms are microorganisms degraded in weeks or months under favorable conditions (Assis & Britto, 2014).

In the search to develop more sustainable materials, cassava starch biofilms have already been developed to mitigate these losses (Veiga-Santos et al., 2008). The mean values of fresh mass loss as a function of time are shown in Fig. 3. The mass loss increased in the two treatments during storage, meaning that the starch biofilms produced of cassava starch are semi-permeable, allowing the fruits to continue breathing and losing mass. At the end of the analysis period, the control group had a 41.88 % loss, followed by T1 (23.77 %) and T2 (25.41 %). There are no statistically significant differences between biofilm treatments. The mass loss occurs through the outlet in the form of water vapor to the environment (Assis & Britto, 2014), so the results obtained demonstrated that the biofilms protected fruits by minimizing water loss through perspiration, avoiding fruit shrinkage and shriveling as a natural indication of ripeness.

This study revealed the efficiency of biofilm coating with and without gelatin to reduce the rate of enzymatic browning and increase the shelf life of bananas. Furthermore, it was possible to verify a reduction in fresh weight loss in the treatments. Besides, no significant difference was observed in the addition of gelatin to the parameters evaluated in the fruit. Moreover, slowing the deterioration of healthy foods is necessary for a reality where nutritional deficiencies are increasingly common, whether due to lack of proper nutrition education or unfavorable economic situations.

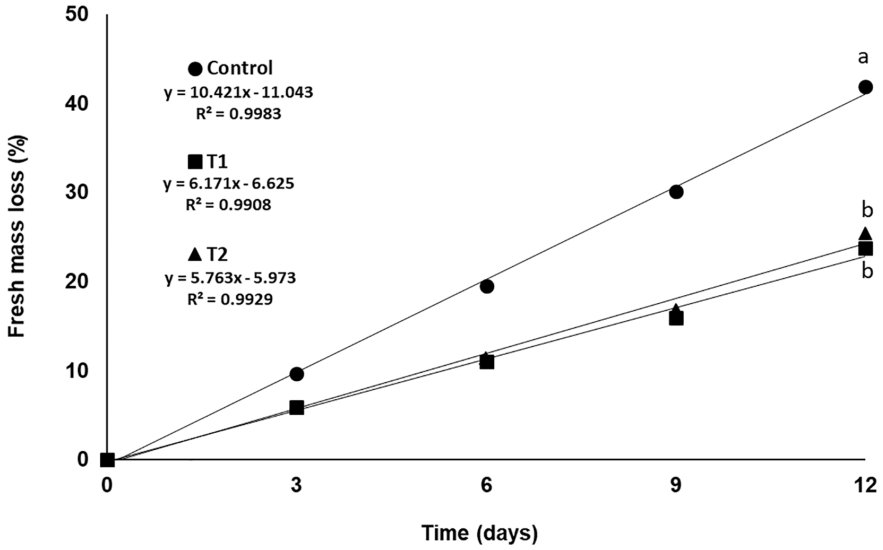

Fig. 3. Fresh mass loss as a function of the two biofilms during 12 days of the experiment. T1 (2.6 % starch / 500 mL of distilled water); T2 (2.6 % starch / 500 mL of distilled water + 1 g of gelatin). Mean values followed by the same lower-case letter do not differ statistically by Tukey's test at 5 % probability test

Polymeric microsystems for use in the controlled release of antibiotics by Emiliane Daher

One of the most significant problems to contemporary public health worldwide is resistance to treatment with antibiotics. It is estimated that antimicrobial resistance causes about 700 thousand deaths every year (Estrela, 2018; Santos, 2004). The forecast is that, by 2050, 10 million deaths annually will be attributed to antimicrobial resistance, which means more deaths than cancer deaths, and the effect on the global economy will be around $100 trillion (Estrela, 2018; https://www.gov.br/anvisa/pt-br/assuntos/noticias-anvisa/2019/resistencia-antimicrobiana-e-ameaca-global-diz-oms). In order to maintain the plasma concentration of the antibiotic and decrease the risk of bacterial resistance using the conventional delivery system, the patient must administer successive doses of the medication at the correct time, which often does not occur (Smith, 2005). For this reason, to improve conventional therapies is crucial in the case of antibiotics. Controlled drug release systems often use synthetically biocompatible and biodegradable polymers, such as poly(lactic acid) – PLA, as carriers for drugs (Uhrich et al., 1999). For this work, the drug cephalexin was chosen, and to improve its encapsulation into the polymer matrix, it was decided to graft a more hydrophilic polymer, polyethylene glycol-PEG, to PLA. In addition, it was decided to add the drug through microemulsion, to try to avoid the initial explosive release, known as «burst release» (Kim et al., 2008). Fig. 4 (a) shows the system used for polymer synthesis, and Fig. 4 (b) the emulsion process used in the production of polymer spheres containing the drug.

The PLA-g-PEG polymer was synthesized, characterized, and the drug was inserted in the microspheres by the emulsion method.

Influence of chemical similarity on the sorption capacity of lignocellulosic fibers by Fernanda Diva

Oil is an essential material and because it is preferably transported by sea, spills frequently occur in the ocean. Several alternatives have

Fig. 4. System used for polymer synthesis (a) and emulsion process used in the production of polymer spheres containing the drug (b)

already been investigated to combat these disasters. A work conducted during the Master Degree studies of Fernanda Diva / LaBioS proved by data mining that the sorption of the material is related to the chemical similarity between the sorber and the sorbent. Fernanda Diva's study is derived from our chemical similarity hypothesis presented elsewhere (Ferreira et al., 2012b). The data mining allowed the gathering of eleven pieces of research developed in the sorption of toluene using vegetable fibers. The extracted data allowed for comparing spectral data reduced to root-mean-square error (RMSE) values and oil sorption capability for every lignocellulosic fiber material from the eleven scientific works. Data analysis proved that the greater the chemical similarity (related to the lowest RMSE obtained values – See Fig. 5), the greater the sorption of the oil by the tested material.

The extraction of data, despite the difficulties caused by the authors' different approaches, proves that the chemical similarity is a critical factor for the sorption of petroleum derivatives in natural polymers. Based on this study, more efficient sorbents may be developed for the sorption of toluene and other components present in oil using vegetable materials that would often be discarded.

Synthesis of thiol-PEG-PBS copolymer by Nathali Ricardo

Cancer is a worldwide public health problem. Therefore, new technologies to combat this disease more efficiently and with fewer side effects attract the attention of the scientific community (Bray et al., 2018; Ferlay et al., 2015). In this context, gold nanoparticles have been shown to be extremely promising. The critical point in using these particles is their stability (Yue et al., 2016). One way to get around this problem is through their coating; one of the coatings most used with AuNPs in pharmacological research is polyethylene glycol (PEG) (Kodiyan et al., 2012; Li et al., 2013). Several studies also proved that PEG conferred prolonged circulation of gold nanoparticles in the blood and, therefore, could show the «Enhanced Permeability and Retention (EPR)» effect, which means more significant accumulation of nanoparticles in tumor tissue (Singh et al., 2018). Additionally, in this study, poly (butylene succinate) (PBS) was used. This polymer is very useful for immobilizing various

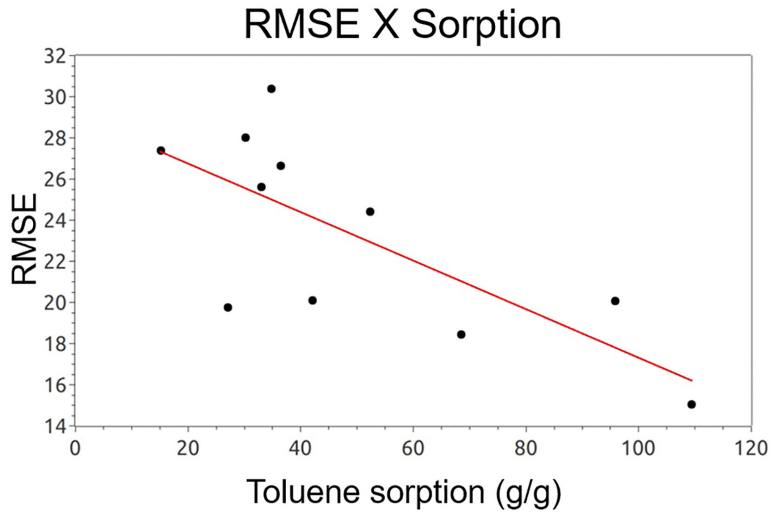

Fig. 5. RMSE ratio and sorption of all analyzed sorption materials

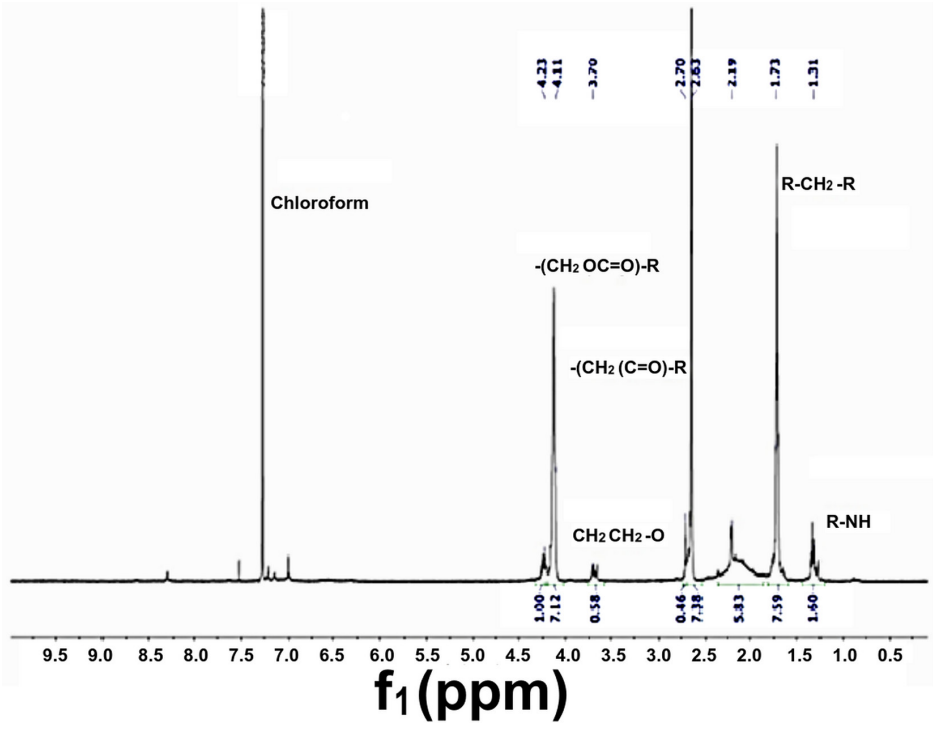

Fig. 6. ^{1}H Nuclear Magnetic Resonance of PBS-PEG

substances, such as medicines, besides having accessible handling capacity (Baldanza et al., 2018; Ferreira et al., 2014).

The nuclear magnetic resonance technique was used to prove whether there was a chemical bond between PEG and PBS and, consequently, the copolymer's formation. The spectrum, shown in Fig. 6, presents chemical shifts located at 1.73 ppm (R-CH_2-R) and 4.11 ppm (–CH_2O(C=O)-R), which correspond to methylene protons in

1,4-butanediol units. The spectrum also shows the chemical shift located at 3.70 ppm referring to methylene protons in ether grouping units (CH_2-CH_2-O) characteristic of polyethylene glycol. In the FTIR spectrum, it is possible to notice that the main expected chemical structures are present in the spectrum, which is another strong indication of obtaining the copolymer.

Therefore, it is possible to see that the proposed interfacial reaction between HS-PEG and PBS modified with TDI was successful; this was proven by the characteristic chemistries of a polyether and polyester in the NMR, and the same was observed in the FTIR spectrum with the presence of characteristic bands of both classes of polymers. It is essential to point out that the purification process allows us to infer that it is a copolymer and not a mixture of polymers. The results of the thermal analysis were within the expected ones and consistent with the data obtained by other authors.

Nanostructured hybrid of magnetite and poly(butylene succinate) with potential application for controlled drug release, magneto hyperthermia, and imaging diagnostics by Rafael Moraes

Nanomedicine is one of the most promising areas of current research in the medical field (Mirza & Siddiqui, 2014). It is the medical application of the unique technologies and properties obtained through manipulating the nanometric scale of materials. The present work aims to build a nanostructured system made of poly (butylene succinate) and magnetite capable of carrying a drug (drug delivery) and releasing it in a controlled manner through specific magnetic stimuli. This technique can reduce side effects mainly in drugs with low bioavailability, such as chemotherapy. Furthermore, this system also aims at the use of magnetohyperthermia, through the use of oscillating magnetic fields, which can heat the magnetite, promoting, for example, the death of tumor cells and sensitizing the cancerous tissue to the action of the drug, resulting in a synergistic effect of the two techniques (Colombo et al., 2012).

Poly(butylene succinate) was synthesized using a 1:1 ratio of succinic acid and 1,4-butanediol (Ferreira et al., 2015). Magnetite was synthesized using the alkaline precipitation method (Moraes et al., 2018a). The hybrid material was synthesized using lactic acid, which forms bonds with the iron hydroxide surface of the magnetite, and later added toluene diisocyanate, which forms urethane bonds with the lactic acid and the polymer. The model drug chosen was ketoconazole due to its properties and the ease of identification during the characterizations. First, the drug and the polymer were dissolved using dichloromethane. Then, water was added to the system under stirring, producing an emulsion where the polymer chains trapped the drug.

The dynamic light scattering results allowed inferring that magnetite presents an average size of 100 nm. Besides, these particles were modified by the polymer chains, and the drug was effectively encapsulated. Fig. 7 shows the SEM micrograph, from which the morphology of the dried hybrid can be observed. The micro-agglomerates retain the drug in the chains, as proved by energy dispersive spectroscopy, which presents chlorine from the drug. The successful synthesis of the hybrid nanostructures and their ability to encapsulate drugs was concluded. The potential to combine different treatments drives all the medicine to a new frontier, where reduced side effects and increased effectiveness of the treatment could come true in a few years. In addition, treatment and diagnosis could be allied in an unprecedented way, as the capacity of the ferromagnetic material to remain in specific tissues, such as tumors, for a time can be used to monitor the effects of medical intervention.

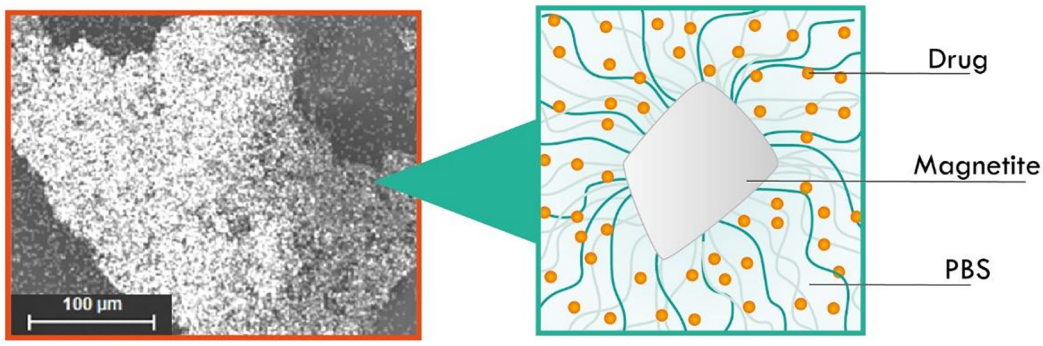

Fig. 7. Micrograph taken by a scanning electron microscope, on the right, energy dispersive spectroscopy showing the element chlorine in emphasis

Heavy metal removal from wastewater using modified biomass
by Marcio Nogueira

Water is an essential asset for the survival of all species of life on planet Earth. Large quantities of industrial wastewater generated in industries such as galvanoplasty, metallurgy, and leather production, in which there are many heavy metals, including chromium, copper, zinc, nickel, lead, and others, are harmful to the environment and living organisms. Numerous studies report the application of biosorption to treat effluents from various sources, with very satisfactory results. Submerged macrophytes have significant potential for bioconcentration of heavy metals due to their larger surface area compared to non-submerged plants (Nogueira et al., 2020). The present work is based on the chemical modification of biological materials to evaluate their efficiency in removing cations of toxic metals, in particular chromium and nickel, present in aquatic environments. The biomass mainly used is of the species *Eichhornia crassipes*, with the chemical modification from the application of an organic anhydride (succinic anhydride). The tests show satisfactory results, with metallic removal rates of around 80 % efficiency. Table 2 shows exciting results for removing chromium and nickel, present in synthetic effluents, using modified biomasses. From the results obtained, it is possible to conclude that the use of chemically modified biomaterials is based on the biocompatibility and stability of these compounds. Moreover, the combination of biosorption with magnetic particles represents an alternative of enormous potential in the treatment of industrial effluents, at the same time representing a non-toxic and low-cost technology.

Table 2. Metal removal efficiency

Biosorbent	Initial concentration					
Modified biomass with succinic anhydride	Cr^{+6}	Ni^{+2}	Cr^{+6}	Ni^{+2}	Cr^{+6}	Ni^{+2}
	10 $mg \cdot L^{-1}$		50 $mg \cdot L^{-1}$		100 $mg \cdot L^{-1}$	
	Metal maximum removal (%)					
	79.1	85.2	80.9	82.4	81.7	83.6

Modification of plant fibers and their applications by Johny Chantre

Vegetable materials have gained space in science and industry because they are less abrasive, biodegradable, have low commercial value, and excellent thermo-mechanical properties. However, chemical modifications are usually necessary for better compatibility with polymeric matrices. Thus, part of Johny Chantre's M. Sc. studies address the main treatments applied to vegetable fibers and their possible applications. The most commonly used treatments for the modification of vegetable substrates are acetylation, sodium bicarbonate, and hornification. These treatments allow the use of waste materials reinforcing polymeric matrices by improving adhesion and compatibility between phases. During the synthesis of polymeric composites from glycerin, castor oil, and maghemite as oil absorbers, milled coffee grounds were added as a filler to lower the costs and improve the final buoyancy of the composite. The results showed that the buoyancy of the composite was improved. However, the addition of vegetable waste as an additive significantly increased water absorption by the composite, increasing its hydrophilic character, thus constituting a competition problem since the objective was the recovery of oil through absorption by the composite. Thus, the acetylation treatment reduced the hydrophilic character of the coffee grounds powder. After the acetylation treatment, the coffee grounds were washed with deionized water and dried at 70 ºC for 24 h. Then, the modified substrate was characterized by Fourier transform infrared spectroscopy (see Fig. 8). The results showed a considerable reduction in the bands around 3500 cm^{-1} of the hydroxyl group, proving that the coffee grounds powder is more hydrophobic than the non-modified analog. For the oil spill cleanup tests, 0.1 g of the composites filled with different amounts of virgin and acetylated coffee grounds (2.5 %, 5 %, and 10 %) were used to remove one gram of oil spilled on seawater. Tests were performed in triplicate. Every time, all the oil was removed from the water. On the other hand, the materials filled with modified coffee grounds powder, compared to the similar non-modified materials, presented an average reduction in the amount of sorbed water equal to (55±39)%, with a confidence limit of 95 %. Therefore, the use of the acetylated filler improved the characteristics of the sorber by

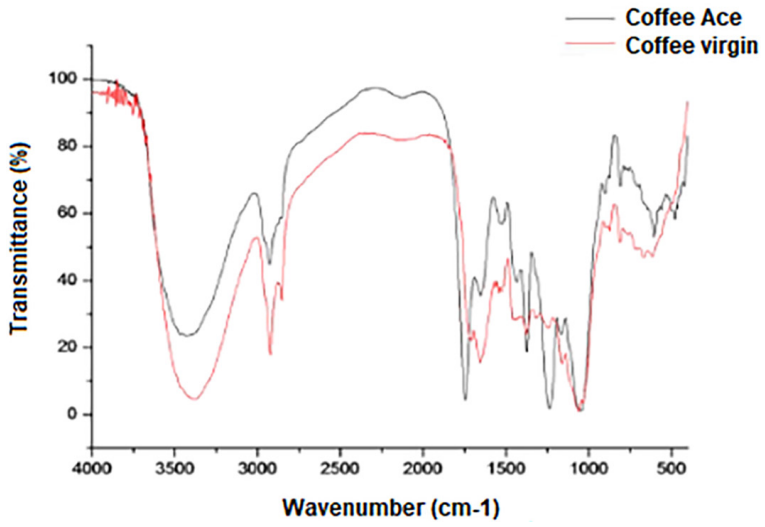

Fig. 8. Fourier transform infrared spectroscopy of non-modified and acetylated (Ace) coffee grounds powder

reducing the water removed and, for this reason, making more straightforward the oil spill cleanup process.

Conclusions and perspectives

Thus, the bibliometric survey presented in this work and the LaBioS' specific contributions to the topic of biopolymers make clear the use of these materials should be encouraged. From our perspective, one of the best ways to spread biopolymers is by modifying their properties. Thus, chemical modifications and nanomodifications via nanoparticles, used as nanofillers or nanosubstrates, must be increasingly researched by the scientific community. So, the use of these new biomaterials will lead us to a healthier relationship with our planet, additionally providing us with real gains in the quality of life and well-being, which are fundamental for our continuous prospering as a civilization.

The data collected here through text mining tools leads us to conclude that the study of the biopolymers is far from being complete. More than that, the correlations shown throughout this research indicate an evolution of the systems studied, proceeding from different clusters, such as the ones dealing with green polymers and biosynthesis of biopolymers, medicine and environmental recovery. Besides that, silicon chemistry possesses crucial relevance to the subsequent developments in this field. In these contexts, LaBioS has contributed by raising a new generation of scientists dealing with the pressure from the short time our planet has to being saved from ourselves and keeping in mind that quality of life must be a premise driving our scientific contributions to the future!

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