Biotechnology Research and Innovation, 2022, 6(1): e202204. https://doi.org/10.4322/biori.202205

SBBiotec SOCIEDADE BRASILEIRA DE BIOTECNOLOGIA

Biotechnology Research & Innovation

www.biori.periodikos.com.br

ARTIGO DE REVISÃO

Xanthan gum: applications, challenges, and advantages of this asset of biotechnological origin

Ingrid F. S. P. C. Furtado[a], Eduardo B. Sydney[a], Sabrina A. Rodrigues[a], Alessandra C. N. Sydney[a,*]

[a]*Bioprocess Engineering and Biotechnology Department, Federal Technological University of Parana – UTFPR, Ponta Grossa Campus, Ponta Grossa, PR, Brazil*

Highlights

- xanthan gum,
- cosmetics,
- biotechnological thickener.

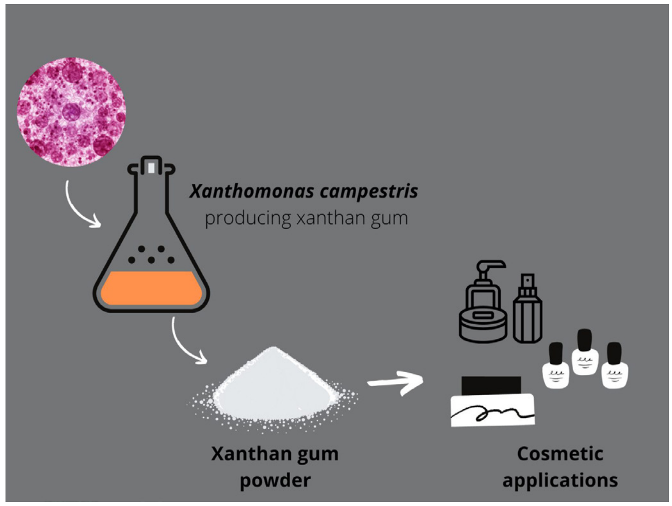
Received 23 November 2021; Accepted 03 May 2022.

KEYWORDS
Xanthan gum;
Cosmetics;
Biotechnological thickener.

Abstract: Cosmetic formulators have numerous thickeners at their disposal to stabilize and increase the viscosity of their formulations. Traditionally, some ingredients are the most widely used for these purposes, such as polyvinylpyrrolidone, polyvinyl alcohol, sodium carboxymethylcellulose, hydroxyethylcellulose, hydroxypropylmethylcellulose, and other cellulose derivatives, as well as carbomer and acrylic acid derivatives (acrylates). As an alternative to chemical compounds, many of them of fossil origin, there are gums of natural origin, such as guar gum, Arabic gum, pectin, and alginate. There are also thickeners of mineral origin, such as aluminum and magnesium silicates, bentonite, and hectorite. However, xanthan gum stands out among all the others due to its biotechnological origin, which allows the insertion of an ingredient that in addition to causing an increase in viscosity can also bring a greater degree of sustainability to the final product. Xanthan gum is an anionic polysaccharide, with high molecular weight, industrially produced by the bacterium *Xanthomonas* sp. This gum forms pseudoplastic solutions, showing good flow behavior. In addition to good formulation stability, it brings good sensory characteristics, such as a pleasant and light structure to the final product. It is versatile, as it can be used in hot and cold formulations and is stable over a wide range of pH and temperature. It can be used in the formulation of toothpaste, creams, lotions, shampoos, etc. This work highlights the properties and applications of xanthan gum in the cosmetic industry, as well as a section dedicated to exposing and discussing the advantages that this asset, of biotechnological origin, brings about its competing ingredients for the final product and, consequently, for the company that uses it.

* Corresponding author.
E-mail: alessandrac@utfpr.edu.br (A. C. N. Sydney).

Graphical Abstract



Introduction

Cosmetics can be defined as substances used to provide aesthetic and hygiene benefits to the user and can be applied to any part of the human body (Corticosteroids, 2014). Among the parts of the body where they are generally used, the facial epidermis, mouth, teeth, hair, nails, and armpits can be highlighted. Thus, each product has a different characteristic for the purpose it is applied to, however, some ingredients are essential, such as the presence of stabilizers and emulsifiers.

Products used for the development of cosmetics can be of synthetic, mineral, or natural origin. However, with the changes in consumer habits, always looking for minimally processed products, the use of materials of natural origin has been favored. Thus, thinking about cosmetic applications, products of biological origin stand out, including guar gum, Arabic gum, xanthan gum, pectin, and alginate. Among the natural alternatives, xanthan gum has evidence due to its emulsifying and stabilizing properties, not depending on climatic and seasonal conditions to be produced, nor its production process can damage the ecosystem, being considered a sustainable alternative. This biopolymer is produced by the genus of bacteria *Xanthomonas* sp., being excreted into the environment as a form of the metabolism of this bacterium. Among the producing species, *Xanthomonas campestris* is chosen due to its high productivity (Lei et al., 2017).

Xanthan gum was discovered in 1960 and was approved by the FDA (Food and Drug Administration) for applications in food products and pharmaceutical products in 1968 (Jindal & Singh Khattar, 2018; Luo & Wang, 2014). Since then, interest in this biopolymer has only grown, since its characteristics are very attractive to the industry compared to other materials on the market. This activity can be used as an emulsifying and stabilizing agent in products such as lotions, shampoos, deodorants, facial creams, body, and facial moisturizers, among many others. These applications are especially favored by their sustainable and non-toxic nature to the environment and the user, with no contraindication (Filomena Freitas et al., 2015). These characteristics are also seen in the market, which estimates a 15% increase in the production of xanthan gum until 2027, which results in about US$ 455.9 million. In this sense, this review highlights the main characteristics, properties, applications, and challenges of using xanthan gum in cosmetics compared to other constituents present in the market.

Methodology

The Scopus database from Elsevier and the Web of Science core collection database from Clarivate Analytics were used for the development of this review. These are databases with the largest number of citations, peer-reviewed, being considered as leaders in this regard (Zhu & Liu, 2020). Terms “xanthan gum” OR xanthan AND cosmetic* were searched in titles, abstracts, and keywords of articles and reviews on June 24, 2021. Documents published in the last five years were used as selection criteria, namely, articles and reviews published between 2017 and 2021.

Only articles or reviews that used xanthan gum as a cosmetic or with applications for this purpose were included in the selected documents. The total number of selected articles was eighteen, as shown in Figure 1 and from these, a critical review was developed regarding the properties, applications, and advantages of using this active biotechnological origin.

Results and Discussion

Features, properties, and applications

Xanthan gum is produced by gram-negative bacteria of the genus *Xanthomonas* sp. of which many species have

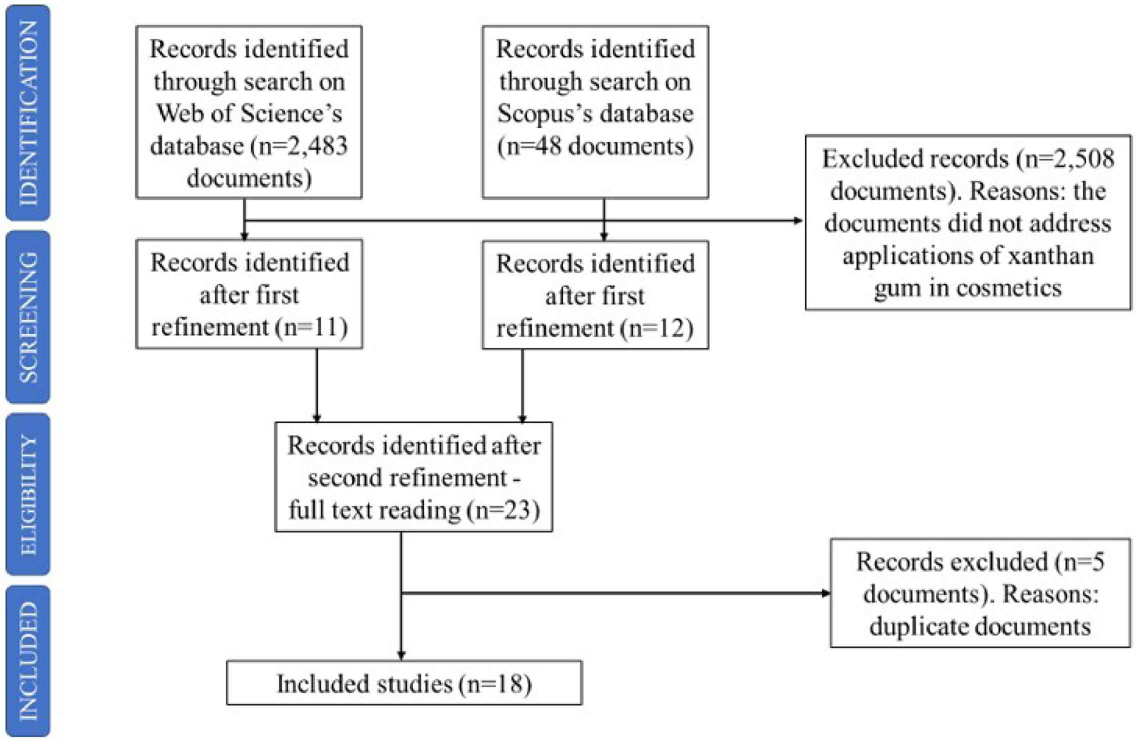


Figure 1. The document selection process in databases.

production capacity, including *X. arboricola, X. axonopodis, X. campestris, X. citri, X. Fragaria, X. gummisudans, X. juglandis, X. phaseoli, and X. vasculorium* (Miranda et al., 2020). However, among those mentioned, the bacterium with the highest industrial efficiency, with about 80% conversion, is *X. campestris,* and therefore it is generally preferred (Lei et al., 2017).

This bacterium is considered a strictly aerobic bacterium. The production of xanthan gum occurs through submerged aerobic fermentation, with a complex and specific culture medium that must contain inorganic salts, carbon portions, trace elements, and a carbon source, such as glucose for example. Cultivation media generally indicated for the production of xanthan gum are reported with Cadmus (1978) and García-Ochoa et al. (2000) (Miranda et al., 2020). After fermentation, the inactivation of the bacterium *X. campestris* must occur, as it is phytopathogenic. This process can be carried by a thermal process out using treatment in an autoclave. The next step is the precipitation of xanthan gum, which happens by the use of solvent, like ethanol. The indicated concentration is three parts of solvent and one part of culture medium with the overnight process for total autonomy. Precipitated xanthan gum must be oven-dried at 80°C and ground to become a powder.

The average molecular weight of xanthan gum is about 2×10^6 Da, however, this value varies according to the producing strain, as well as the growing conditions to which it was subjected, that is, carbon source, nitrogen, variation of pH, temperature, and agitation (Carvalho et al., 2021). Xanthan gum is an extracellular polysaccharide with an acidic character due to the presence of acidic groups in its structure, leading to an electrostatic repulsion effect during the interaction between the side chains (Carvalho et al., 2021; Bokov Dmitry et al., 2020). The structure of this biopolymer consists of a backbone composed of cellobiose repeating units while the side chains are formed by d-mannose (β-1.4), d-glucuronic acid (β-1.2), and d-mannose, which are linked to glucose molecules by α-1,3-type bonds (Carvalho et al., 2021), as illustrated in Figure 2.

Pyruvate and acetyl are substituents that present a variable percentage in the side chains, so that the higher the pyruvate content present in the structure, the greater the viscosity and thermal stability presented by this biopolymer (Becker, 1998). The way the side chains are arranged is related to the rigidity of the structure, a factor that favors the various applicability in the cosmetic area, as well as a characteristic that highlights this gum among the others (Lei et al., 2017). Due to the chemical structure of xanthan gum shown in Figure 2, it has several interesting properties from a cosmetic point of view, such as ease of keeping the skin hydrated for longer, anti-aging activity, controlled delivery of actives to the skin, gelling effect, and sensory improvement to the skin. cosmetics. From a technical point of view, the properties of high viscosity even at low concentrations, resistant pH, being soluble in hot or cold water, being non-toxic, pseudo-plasticity stand out (Nordin et al., 2020).

Fagioli et al. (2018) evaluated in their work the effect of using different gums (glucomannan, xanthan gum, tara gum, guar gum, konjac gum, and gellan gum) against variations in temperature and pH such that xanthan gum presented positive characteristics such as maintenance of viscosity under temperature changes and pH changes. Furthermore, Woźniak et al. (2021) mention that they obtained positive results using xanthan gum as an emulsifying agent and stabilizer in oily solutions. These results are in line with what was highlighted by Nordin et al. (2020).

However, all the characteristics described are essential for the development of cosmetics, since formulations seek to obtain results of stability, emulsion, and sensory appearance that are positive and pleasing to the user. Allied to these factors, more and more products have been developed using xanthan gum with the premise of acting in the aforementioned aspects, including Active Powder® Volu Lips LS 9773, used to formulate lip moisturizers. In addition, many products have their action amplified with the use of xanthan gum, as it makes the product's active compound to be easily absorbed by the skin and ensures that it does not lose water to the environment.

In this perspective, Nordin et al. (2020) report in their work that the efficiency of xanthan gum depends on the concentration used for the desired purpose, varying from product to product. Thus, Table 1 presents the different concentrations of xanthan gum for different products in which it can be used, as well as its main functionality in these products.

Krstono (2015) used different concentrations of xanthan gum, ranging from 0.01% (w/w) to 0.2% (w/w) to evaluate the influence of concentration on emulsifying properties in a water-oil system. As a result, the authors found that the greater the concentration of xanthan gum, the greater the increase in the contact surface of the droplets and,

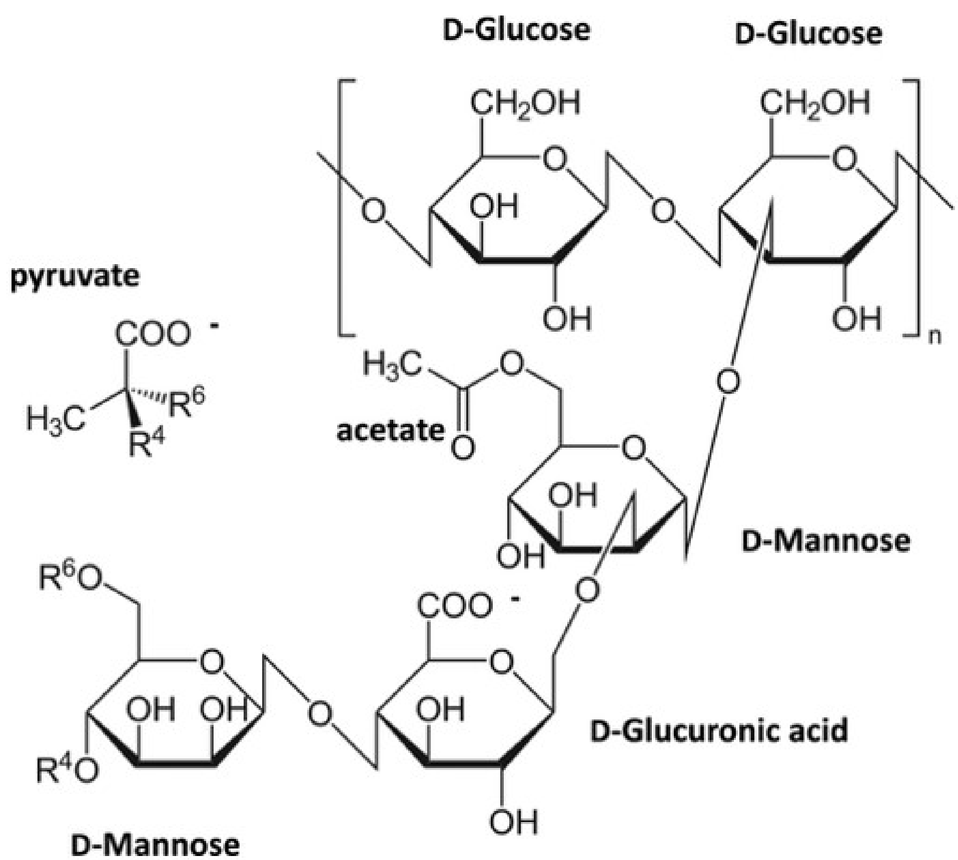


Figure 2. Representation of the chemical structure of xanthan gum repeat units. Adapted from Petri (2015).

Table 1. Cosmetic applications of xanthan gum.

Application	Concentration (%)	Functionality
Creams and suspensions	0.1-1	Emulsion stabilizer
Toothpaste, shampoos, and lotions	0.2-1	Thickener and stabilizer
Baby products	0.2-0.6	Stabilizer formulations
Enamels and hair colorings	0.2-6	Thickener and stabilizer
Deodorants	0.005-0.6	Stabilizer

Adapted from Fiume et al. (2016).

consequently, the lower the rheology of the solution. These characteristics are important as they determine the appearance that will be obtained for the cosmetic of interest. In this sense, as illustrated in Table 2, the region in which the cosmetic will be applied depends on the concentration used, considering that concentrations higher than those recommended can promote adverse effects to the user (Nordin et al., 2020).

Table 2. Main characteristics of polymers of biological, mineral, and synthetic origin.

Polymers of natural origin	Characteristics	References
Guar gum	- Produced by legumes, they are insoluble in organic solvents, but soluble in water;	Thombare et al. (2016)
	- Provides increased viscosity of aqueous solutions, achieving greater stability in cold water.	
Gum Arabic		
	- Produced by legumes, soluble in water and has emulsifying characteristics in oils;	Dauqan & Abdullah (2013)
Pectin	- It has Newtonian behavior and heating can degrade the gum structure.	
		Ciriminna et al. (2015)
Alginate	- Extracted from lemon, soluble in water, has thickening and stabilizing properties;	
	- Its production process can cause risks to the environment.	
Polymers of mineral origin		Ahmad et al. (2015).
Aluminum	- Produced by brown algae and some genera of bacteria, such as *Pseudomonas* sp.;	
and magnesium silicate	- It has stabilizing and emulsifying activity, presenting good biocompatibility;	
Bentorite and Hectorite	- Its production can cause risks to the environment.	Moraes et al. (2017)
Polymers of synthetic origin	- It presents ion exchange capacity, dispersibility, and plasticity effect in solutions;	
	- Acts as emulsifying and stabilizing agent;	
Polyvinylpyrrolidone (PVP)	-Under agitation can reduce the viscosity of the medium.	Kurakula & Rao (2020)
Polyvinyl alcohol (PVA)	- It has a synthetic origin, is soluble in water, inert, and non-toxic to the user;	Asthana et al. (2020)
	- It is temperature resistant, stable in pH ranges, and biocompatible;	
	- Acts as emulsifying agent and stabilizer in solutions.	
Carboxymethylcellulose sodic		Feddersen & Thorp (1993)
	- Of synthetic origin, it acts promoting the change of viscosity of solutions.	
	- Of synthetic origin, presents non-Newtonian behavior in solutions;	Fiume et al. (2017)
	- Used to provide increased viscosity and stability;	
Alkyl Acrylate	- Stable in wide pH range and temperature resistant, however high temperatures, for long periods, can promote its degradation;	
		Saha & Bhattacharya (2010)
	- Of the synthetic origin and can be used as absorbents, film former, emulsion stabilizers, viscosity-increasing agents, suspension agents, binders, or skin conditioning agents.	
Methylcelulose and hidroxipropylcelulose		
	-Of synthetic origin, it has increased viscosity but is independent of pH and the addition of electrolytes.	

Advantages and challenges of xanthan gum over other materials

The properties of xanthan gum are highlighted in the previous section indicate that this biopolymer could have several advantages compared to other thickeners of biological, chemical, and mineral origin. In this sense, Table 2 illustrates the main characteristics of these other polymers to compare their characteristics with xanthan gum.

Xanthan gum, unlike pectin, guar gum, and Arabic gum, which are obtained from fruit and leguminous sources respectively, is produced from microorganisms, which makes its use viable regardless of climatic conditions and time of year, already standing out in this question. Furthermore, other aspects that can be highlighted about xanthan gum compared to products of natural origin is that it can be applied in organic solvents, acids, bases, and even under saline conditions, without having its viscosity changed (Nordin et al., 2020).

Still, on materials of natural origin, alginate can be obtained from brown algae or bacteria of the genus *Pseudomonas* sp. Its main characteristic is its gelling capacity, which makes it attractive in encapsulation applications, while the outstanding characteristics of xanthan gum are its ability to promote viscosity and stability to the environment, which is why in many cosmetic applications it is preferable (Saha & Bhattacharya, 2010). Although alginate has been extensively studied for encapsulation applications, xanthan gum has been used due to its good biocompatibility with biological systems (Ding et al., 2019).

Regarding the use of mineral materials such as calcium and magnesium silicates, bentorite, and hectorite, despite being released for use in cosmetics, they can accumulate in the body, especially in the liver, and cause harm to the user (Younes et al., 2018). In 2016, the FDA advised the American population not to use bentorite due to the accumulation of lead in the materials (Food and Drug Administration, 2016). Although hectorite is considered safe for health, this factor depends on the concentration used in the cosmetics and on the country that is using this material, that is, some countries may not follow the recommended standards, increasing the concentration in cosmetics.

Furthermore, xanthan gum has a similar capacity to polymers of mineral and synthetic origin in forming pseudoplastic films, however, it has the advantage of its biological origin, in addition to the fact that it does not cause any harm to the user's health. The pseudo-plasticity effect is very important in cosmetics and was verified by (Miranda et al., 2020) during the development of the study on the characterization of different oils of natural origin, where the authors used xanthan gum as a stabilizing agent. This characteristic was also described by Abu et al. (2021) during research on the properties of xanthan gum.

In contrast to all production processes shown by the polymers mentioned in Table 2, xanthan gum is the only biopolymer that has low toxicity to the environment and is therefore considered a sustainable product. In addition, another positive aspect of xanthan gum compared to other polymers is its ability to cross-link different materials, which can promote an increase or reduction in its activity, a characteristic used and cited by different researchers (Petri, 2015; Miranda et al., 2020; Woźniak et al., 2021).

In addition to being non-toxic to the environment, xanthan gum does not accumulate in the body, nor is it toxic to the user, unlike materials of synthetic origin such as alkyl acrylates, which have bioaccumulative potential already reported in the literature (New Jersey Department of Health, 2017). Furthermore, materials such as polyvinyl alcohol and polyvinylpyrrolidone, although considered safe to health, as they are of synthetic origin, end up being extremely processed, which makes their use questionable.

Sodium carboxymethylcellulose, methylcellulose, and hydroxyethylcellulose are polymers that originate from cellulose, but to be obtained they need a degree of the chemical process due to the reactions involved. These materials are capable of promoting increased viscosity and stability for solutions, similar to that of xanthan gum, however, under high shear stresses, they lose stability, as observed by Gilbert et al. (2013) in their evaluation of rheology with carboxymethylcellulose, methylcellulose, and hydroxyethylcellulose compared to xanthan gum. According to the authors, xanthan gum was the only material capable of not being affected by tensions, a characteristic that is fundamental for cosmetics.

A comparison between the final product xanthan gum versus hydroxyethylcellulose shows that xanthan gum, in addition to presenting superior functional characteristics, also has a financial value 55% cheaper than the other polymer. The same relationship, when analyzed for guar gum, illustrates xanthan gum being 26% more economical. Due to the versatile and attractive characteristics of xanthan gum compared to other polymers for cosmetic applications, its production in 2020 yielded around US$ 397 million and it is estimated that in 2027 it should reach the US$ 455.9 million mark (an increase of 15%), produced mostly by American companies, highlighting Archer Daniels Midland Company, Cargill, DowDuPont, Ingredion and Jungbunzlauer Suisse AG (ReportLinker, 2020). As it is a bioproduct produced mainly by a few companies, there is a lot of industrial secret about this very complex and profitable process.

This disparity can also be perceived by the number of patents generated by the United States of America, which is the leading country in the production of inventions from 1970 to February 2022. The US has a total of 15,314 inventions, followed by Japan (8,231), Germany (6,376), and France (5,383). In this sense, the companies that presented the most inventions were L'oreal (1,903), Shiseido Co LTD (1,488), Kao Corp (1,221), and Pola Chem Ind Inc (801). According to Espacenet, one of the reference platforms for patent searches, when searching for the term "xanthan gum AND cosmetics" the three most relevant patents of the year 2021 are reported by China and refer to the use of xanthan gum with different molecular weights for the delivery of dermatological actives (CN113559015A), describes the methodology for preparing xanthan gum molecule with malic acid for cosmetic applications (CN113185620A) and the methodology for preparing lysozyme nanoparticles with xanthan gum for cosmetic applications (CN112972393A), since this technique increases the biocompatibility and stability of the solution.

Therefore, a great challenge and also an opportunity for this process is to make it more competitive to favor small companies and, as a consequence, obtain a product with attractive market value so that the cosmetic industries can replace the use of other polymers with xanthan gum.

Conclusions

There are no different types of thickeners and stabilizers that can be used in cosmetic formulations. Currently, materials of biological origin have been favored due to their ecological footprint and minimal processing. Among all the materials added during the review, xanthan gum is the most attractive biopolymer because, in addition to its rheological activity, it has moisturizing, anti-aging, and positive sensory properties, characteristics that make it stand out from the rest. Furthermore, its use in cosmetics can favor the active principle of other compounds due to its ability to keep the skin water.

Xanthan gum is non-toxic to the environment and the user, having a production route considered to be sustainable. Therefore, an increase in cosmetic products formulated with this biopolymer was noted, which justifies a prospect of a 15% increase in production by 2027. A major challenge and also an opportunity for this process is to make it more competitive, since today, companies learn to evolve xanthan gum and have adequate knowledge on how to develop this complex process on an industrial scale.

Acknowledgements

The authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES) – Brazil for the financial support.

References

Abu, M. H., Goda, E. S., Gab-Allah, M. A., Hong, S. E., Pandit, B., Lee, S., Gamal, H., Rehman, A., & Yoon, K. R. (2021). Xanthan gum-derived materials for applications in environment and eco-friendly materials: A review. *Journal of Environmental Chemical Engineering*, *9*(1), 104702. http://dx.doi.org/10.1016/j.jece.2020.104702.

Ahmad, N. H., Mustafa, S., & Man, Y. B. C. (2015). Microbial polysaccharides and their modification approach: A review. *International Journal of Food Properties*, *18*(2), 332-347. http://dx.doi.org/10.1080/10942912.2012.693561.

Asthana, N., Pal, K., Aljabali, A. A. A., Tambuwala, M. M., de Souza, F. G., & Pandey, K. (2020). Polyvinyl alcohol (PVA) mixed green-clay and aloe vera based polymeric membrane optimization: Peel-off mask formulation for skin care cosmeceuticals in green nanotechnology. *Journal of Molecular Structure*, *1229*, 129592. http://dx.doi.org/10.1016/j.molstruc.2020.129592.

Becker, I.A., 1998. Xanthan gum biosynthesis and application : a biochemical / genetic perspective 145–152.

Bokov Dmitry, O., Sokurenko Maria, S., Malinkin Alexei, D., Khromchenkova Elena, P., Shevyakova Lyudmila, V., & Bessonov Vladimir, V. (2020). Physiochemical features, qualitative and quantitative analysis, present status physiochemical features, qualitative and quantitative analysis, present status and application prospects of polysaccharide gums. *International Journal of Pharmaceutical Quality Assurance*, *11*(1), 154-162.

Cadmus, M.C., Knutson, C.A., Lagoda, A.A., Burton, K.A., 1978. Synthetic Media for Production of Quality Xanthan Gum in 20 Liter Fermentors * XX, 1003–1014.

Carvalho, L.T., Vieira, T.A., Zhao, Y., Celli, A., Medeiros, S.F., Lacerda, T.M., 2021. Recent advances in the production of biomedical systems based on polyhydroxyalkanoates and exopolysaccharides International Journal of Biological Macromolecules Recent advances in the production of biomedical systems based on polyhydroxyalkanoates and exopolysaccharides. Int. J. Biol. Macromol. 183. https://doi.org/10.1016/j.ijbiomac.2021.05.025

Ciriminna, R., Chavarría-Hernández, N., Inés Rodríguez Hernández, A., & Pagliaro, M. (2015). Pectin: A new perspective from the biorefinery standpoint. *Biofuels, Bioproducts & Biorefining*, *9*(4), 368-377. http://dx.doi.org/10.1002/bbb.1551.

Corticosteroids, C., 2014. Cosmetics and Personal Care Products, Third Edition. ed, Encyclopedia of Toxicology. Elsevier. https://doi.org/10.1016/B978-0-12-386454-3.00979-9

Dauqan, E., & Abdullah, A. (2013). Utilization of gum arabic for industries and human health. *American Journal of Applied Sciences*, *10*(10), 1270-1279. http://dx.doi.org/10.3844/ajassp.2013.1270.1279.

Ding, B., Li, C., Pan, M., Chiou, Y., Li, Z., Wei, S., Yin, X., 2019. Microencapsulation of xanthan gum based on palm stearin / beeswax matrix as wall system. J. Food Process Eng. 1–8. https://doi.org/10.1111/jfpe.13102

Fagioli, L., Pavoni, L., Logrippo, S., Pelucchini, C., Rampoldi, L., Cespi, M., Bonacucina, G., Casettari, L., 2018. Linear Viscoelastic Properties of Selected Polysaccharide Gums as Function of Concentration , pH , and Temperature. https://doi.org/10.1111/1750-3841.14407

FDA, 2016. FDA Warns Consumers Not to Use "Best Bentonite Clay" [WWW Document]. Food Drug Adm. URL https://www.fda.gov/drugs/drug-safety-and-availability/fda-warns-consumers-not-use-best-bentonite-clay

Feddersen, R. L., & Thorp, S. N. (1993). *Sodium carboxymethylcellulose* (3rd ed.). San Diego: Academic Press.

Filomena Freitas; Vıtor D. Alves; Maria A. M. Reis, 2015. Bacterial Polysaccharides: Production and Applications in Cosmetic Industry. Polysaccharides Bioactivity Biotechnol. 2018–2039. https://doi.org/10.1007/978-3-319-16298-0

Fiume, M. M., Heldreth, B., Bergfeld, W. F., Belsito, D. V., Hill, R. A., Klaassen, C. D., Liebler, D. C., Marks Junior, J. G., Shank, R. C., Slaga, T. J., Snyder, P. W., & Andersen, F. A. (2016). Safety Assessment of microbial polysaccharide gums as used in cosmetics. *International Journal of Toxicology*, *35*(1, Suppl), 5S-49S. http://dx.doi.org/10.1177/1091581816651606. PMid:27383198.

Fiume, M. M., Heldreth, B., Boyer, I., Bergfeld, W. F., Belsito, D. V., Hill, R. A., Klaassen, C. D., Liebler, D. C., Marks Junior, J. G., Shank, R. C., Slaga, T. J., Snyder, P. W., & Andersen, F. A. (2017). Safety assessment of cross-linked alkyl acrylates as used in cosmetics. *International Journal of Toxicology*, *36*(5, Suppl 2), 59S-88S. http://dx.doi.org/10.1177/1091581817707927. PMid:29025328.

García-Ochoa, F., Santos, V. E., Casas, J. A., & Gómez, E. (2000). Xanthan gum: Production, recovery, and properties. *Biotechnology Advances*, *18*(7), 549-579. http://dx.doi.org/10.1016/S0734-9750(00)00050-1. PMid:14538095.

Gilbert, L., Picard, C., Savary, G., Grisel, M., 2013. Rheological and textural characterization of cosmetic emulsions containing natural and synthetic polymers : relationships between both data. Colloids Surfaces A Physicochem. Eng. Asp. 421, 150–163. https://doi.org/10.1016/j.colsurfa.2013.01.003

Jindal, N., Singh Khattar, J., 2018. Microbial Polysaccharides in Food Industry, in: Biopolymers for Food Design. Elsevier Inc., India, pp. 95–123. https://doi.org/10.1016/B978-0-12-811449-0.00004-9

Krstono, V., 2015. Food Hydrocolloids Influence of xanthan gum on oil-in-water emulsion characteristics stabilized by OSA starch 45, 9–17. https://doi.org/10.1016/j.foodhyd.2014.10.024

Kurakula, M., & Rao, G. S. N. K. (2020). Pharmaceutical assessment of polyvinylpyrrolidone (PVP): As excipient from conventional to controlled delivery systems with a spotlight on COVID-19 inhibition. *Journal of Drug Delivery Science and Technology*, *60*, 102046. http://dx.doi.org/10.1016/j.jddst.2020.102046. PMid:32905026.

Lei, S., Edmund, T.F., Polytechnic, T., 2017. Polysaccharides, Microbial 1–19. https://doi.org/10.1016/B978-0-12-809633-8.13102-4

Luo, Y., Wang, Q., 2014. Recent development of chitosan-based polyelectrolyte complexes with natural polysaccharides for drug delivery. Int. J. Biol. Macromol. 64, 353–367. https://doi.org/10.1016/j.ijbiomac.2013.12.017

Miranda, A. L., Costa, S. S., Assis, D. J., Jesus, C. S., Guimarães, A. G., & Druzian, J. I. (2020). Influence of strain and fermentation time on the production, composition, and properties of xanthan gum. *Journal of Applied Polymer Science*, *137*(15), 1-11. http://dx.doi.org/10.1002/app.48557.

Moraes, J. D. D., Bertolino, S. R. A., Cuffini, S. L., Ducart, D. F., Bretzke, P. E., & Leonardi, G. R. (2017). Clay minerals: Properties and applications to dermo-cosmetic products and perspectives of natural raw materials for therapeutic purposes: A review. *International Journal of Pharmaceutics*, *534*(1-2), 213-219. http://dx.doi.org/10.1016/j.ijpharm.2017.10.031. PMid:29038067.

New Jersey Department of Health, 2017. Hazardous substance fact sheet.

Nordin, N. Z., Rashidi, A. R., Dailin, D. J., Abd. Malek, R., Azelee, N. I. W., Abd. Manas, N. H., Selvamanil, S., Zaidel, D. N. A., Abd Alsaheb, R. A., Sukmawati, D., & El Enshasy, H. (2020). Xanthan biopolymer in pharmaceutical and cosmeceutical applications: Critical review article. *Bioscience Research*, *17*, 205-220.

Petri, D. F. S. (2015). Xanthan gum: A versatile biopolymer for biomedical and technological applications. *Journal of Applied Polymer Science*, *132*(23). http://dx.doi.org/10.1002/app.42035.

ReportLinker, 2020. Global Xanthan Gum Industry [WWW Document]. Globe Newswire. URL https://www.globenewswire.com/news-release/2020/12/15/2145513/0/en/Global-Xanthan-Gum-Industry.html

Saha, D., & Bhattacharya, S. (2010). Hydrocolloids as a thickening and gelling agents in food: A critical review. *Journal of Food Science and Technology*, *47*(6), 587-597. http://dx.doi.org/10.1007/s13197-010-0162-6.

Thombare, N., Jha, U., Mishra, S., & Siddiqui, M. Z. (2016). Guar gum as a promising starting material for diverse applications: A review. *International Journal of Biological Macromolecules*, *88*, 361-372. http://dx.doi.org/10.1016/j.ijbiomac.2016.04.001. PMid:27044346.

Woźniak, M., Kowalska, M., Tavernier, S., & Żbikowska, A. (2021). Enzymatically modified fats applied in emulsions stabilized by polysaccharides. *Biomolecules*, *11*(1), 49. http://dx.doi.org/10.3390/biom11010049.

Younes, M., Aggett, P., Aguilar, F., Crebelli, R., Dusemund, B., Filipič, M., Frutos, M. J., Galtier, P., Gott, D., Gundert-Remy, U., Kuhnle, G. G., Leblanc, J. C., Lillegaard, I. T., Moldeus, P., Mortensen, A., Oskarsson, A., Stankovic, I., Waalkens-Berendsen, I., Woutersen, R. A., Wright, M., Boon, P., Gürtler, R., Mosesso, P., Parent-Massin, D., Tobback, P., Chrysafidis, D., Rincon, A. M., Tard, A., & Lambré, C. (2018). Re-evaluation of calcium silicate (E 552), magnesium silicate (E 553a (i)), magnesium trisilicate (E 553a (ii)), and talc (E 553b) as food additives. *EFSA Journal*, *16*(8), e05375. PMid:32626019.

Zhu, J., & Liu, W. (2020). A tale of two databases: The use of Web of Science and Scopus in academic papers. *Scientometrics*, *123*(1), 321-335. http://dx.doi.org/10.1007/s11192-020-03387-8.