



Review

Applicability of bacterial cellulose in cosmetics – bibliometric review



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ABSTRACT

The search for innovation and new approaches to mitigate environmental impact encourages the cosmetic industry to explore new methodologies and materials. Bacterial cellulose has been the focus of research because it has high biocompatibility, skin adhesion, and water retention, in addition to being a sustainable alternative material. This review paper explored the perspectives emerging in the scientific literature on the use of bacterial cellulose in cosmetics. This bibliometric review was performed using four databases along with three software programs to obtain a more complete analysis. The search identified 18 articles related to the topic. Because the highest number of articles was published in the year 2019, it was estimated that more publications will appear in the near future. Studies have demonstrated the potential for the use of bacterial cellulose in face masks for the delivery of active compounds and increased skin hydration, and it can also act as an emulsion stabilizer.

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1. Introduction

There are several causes of skin changes, among them, intrinsic factors, such as decreased fibroblastic and collagen function, and extrinsic factors, including ultraviolet radiation, smoking, stress, and lack of basic skin care, leading to the appearance of expression lines, hyperchromia, and early aging [1]. To mitigate these changes, mainly antioxidant and moisturizing active agents are required. With facial procedures and the regular use of masks with cosmetic actives, it is possible to maintain skin hydration levels and a healthy stable hydrolipid layer, thus, the loss of transcutaneous water is attenuated, keeping the skin younger in appearance [2].

With easier access to information and increased awareness of the need for skin care, there is a growing number of cosmetic consumers. The world cosmetics market generated US \$128.9 billion in 2018 and, with the boost in this area, cosmetic production has increased 4.5 % annually over the last two decades [3,4]. Similar to other industries, this sector has been adopting green approaches to cosmetics, with organic and natural composition and the companies that value sustainability are gaining space [5]. A survey by Feng et al. (2018) found that people are becoming more responsible with regard to environmental concerns in the dermocosmetics area. In one study, 73 % of the respondents reported reading product composition information, while 77 %

reported a high chance of purchasing sustainable cosmetic products in the coming years [6].

This shift could be occurring due to education combined with a concern for the environment, which generates so-called 'ethical consumerism', where individuals consider the raw materials used in cosmetics and their ecological implications [7]. Numerous cosmetic compositions are formulated with petroleum derivatives, a non-renewable resource that produces residues that are difficult to degrade [8]. Products, such as skin scrubs and masks, result in one of the most serious environmental problems, i.e., the generation of bio accumulative microplastics, mainly in the oceans, which can cause the death of marine species [9].

Also notable are the environmental imbalances and impact of the uncontrolled use of natural resources, threatening the healthy development of ecosystems and directly affecting society [10]. In 2015, to address these issues, 150 world leaders together with the UN adopted 17 Sustainable Development Goals (SDGs). In particular, Goal 12.5 seeks to ensure sustainable production and consumption standards, aimed at reducing the generation of waste by the year 2030 [11].

Prior to this, the cosmetics industry had been seeking innovations, with new products, processes, innovating in supply sources, meeting market concerns and reducing environmental pollutants [12]. Bacterial cellulose has been the target of groundbreaking research in the cosmeceutical area, because all celluloses biodegrade in the natural environment [13,14].

Since 1980, bacterial cellulose has been used in wound care, including burns, as it ensures a moist environment, is an effective physical barrier against pathogens, creates good conditions for

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tissue regeneration, and is recommended for temporary skin wound coverage. This biocompatibility occurs due to the similarity with components of the cell matrix, such as collagen. Studies have used bacterial cellulose for meniscal cartilage implants, bone tissue implants, and primarily as a delivery system for drugs and other active compounds [15,16,13].

Bacterial cellulose becomes a polymer of great interest for future research, as it has shown high biocompatibility with human tissues [17]. Rajwade et al. (2015) reported that bacterial cellulose has high water retention capacity and permeability and can be used for skin permeation of hydrophilic actives, such as moisturizers and anti-aging agents, besides obtaining a mask with a whitening effect [16,18].

Pacheco et al. (2017) used 69 volunteers for the application of bacterial cellulose as a mask for the delivery of cosmetic actives, three times a week for two months. The mask ensured good adhesion to the skin, improved moisture, and increased hydration by 76 %, proving to be a promising alternative for skin treatments [19]. Despite these interesting findings, few authors in the literature have measured the interest in the applicability of biocellulose in cosmetics.

Therefore, the aim of this paper was to explore the perspectives emerging in the scientific literature regarding the use of bacterial cellulose in cosmetics *via* a bibliometric review.

2. Material and methods

In this study a bibliometric review was conducted, which has been described by Araújo (2006) as the quantitative analysis of scientific production stored in selected bibliographic databases [20]. The keywords used were: "bacterial cellulose" and "cosmetics". Bibliometrics was performed using the databases accessed through the CAPES periodicals portal, which contains interdisciplinary content, namely:

2.1. SCOPUS

Features peer-reviewed academic titles, conference proceedings, trade publications, book series, and office patents. Features supported for bibliometric analysis include the identification of authors and affiliations, citation analysis, publication analysis, and H index.

2.2. Web of science

This base guarantees access to bibliometrics and abstracts in all areas of knowledge. Tools are available for citation analysis, references, and allowing bibliometric analysis. It covers approximately 12,000

journals and consults five collections: Science Citation Index Expanded (SCI-EXPANDED).

2.3. ProQuest METADEX

An interdisciplinary database that features full-text and expert indexing of global literature. It offers its users the tools and content to keep up with the latest field research.

2.4. Science direct

Features multidisciplinary content and combines technical and scientific publications with full peer-reviewed texts. It covers 24 interdisciplinary collections and features articles from over 3800 journals and 39,000 book titles.

At first, the keywords were applied generally and then, after filtering, only in relation to the type of document, where articles were selected, because they were peer reviewed in full and associated with greater credibility. Data was collected from 2009 to 2020. The inclusion criteria were the articles that contained the keywords in the title, abstract, or article body. Exclusion was performed for repeated articles.

The title and abstract of each article were read and those that did not align with the theme were excluded. With the bibliometric process applied to this research, it was possible to select the articles that addressed the theme of the use of bacterial cellulose for cosmetic purposes. At this stage, the articles were reviewed in pairs. They were moved to a folder in the Mendeley Developer software (Elsevier, version 1803, London, England) and saved as an Information Systems Research (RIS) file. Using Google Scholar[®] the authors analyzed the number of citations in the literature of each article.

With the aid of VOSviewer software (CWTS BV, v.1.6.13, Leida, Netherlands), it was possible to generate a cluster with the most cited keywords in the articles, that is, those that obtained two or more occurrences. With this software it was viable to analyze the correlation of word frequency and the year with the highest citations. To ensure excellence in the qualitative analysis, in the development of the discussion of this article the authors used the Atlas Ti software (ATLAS.ti Scientific Software Development BmbH, version 7), in which it was possible to correlate and group the terms that were found in the previously mentioned clusters.

Using the Espacenet patent base, the search for the number of patents published with the keywords "bacterial cellulose" and cosmetics was carried out between 2009 and 2020. The Espacenet base contains more than 90 million patent documents from different countries, is maintained by the European Patent Office (EPO). It allows searching the bibliographic data of patent documents.

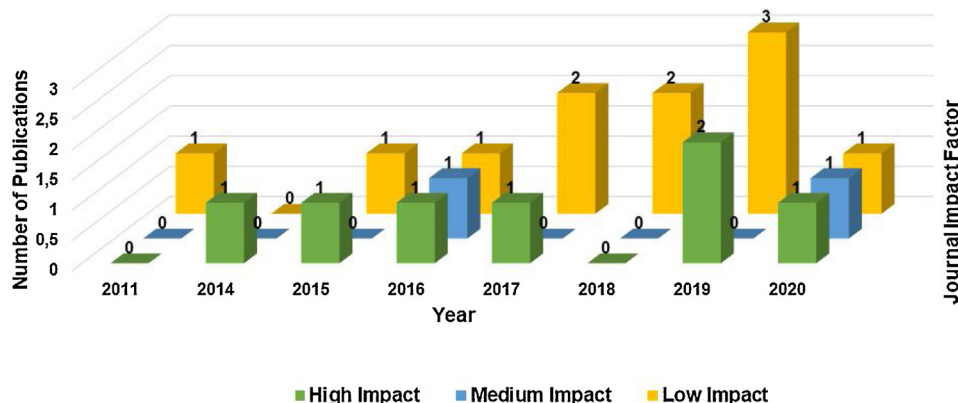


Fig. 1. Correlation between the impact factor of the Journals and the annual number of publications.

3. Results and discussion

A total of 488 articles were initially found but 468 were subsequently excluded following the criteria established in the methods. Only articles that addressed the theme of the use of bacterial cellulose for cosmetic purposes were included in the final selection.

In the research performed, in relation to the theme addressed, 5 articles were found in the SCOPUS database, 2 articles in ProQuest, 7 articles in Web of Science, and 6 articles in ScienceDirect, for a total of 20 articles. Fig. 1 shows the years of publication in parallel with the impact factor of the journals.

The years 2009, 2010, 2012, and 2013 did not present publications with the selected keywords. The year 2019 presented the largest number of articles ($n = 5$). Therefore, a growing interest in and publications on the topic addressed can be observed, which is to be expected because bacterial cellulose has provided excellent results in several areas including the biomedical and pharmaceutical areas and more recently cosmetics [15,12,16].

Identifying then that this area of research is still maturing, because the articles found are mainly in low impact journals. Thus, there is a need for publications in journals with higher impact factors, which have greater credibility in the scientific environment and require in-depth work. In addition, the general scarcity of content in this area [13] highlights the urgent need for scientific production on the subject to enhance its development.

The type of study that was performed in each article was examined and the methodological strategies were analyzed to ascertain which aspects need to be added in the scientific literature, which tests can be performed, and how bacterial cellulose can be applied. Of the articles found, 18 were case studies and laboratory research and only two were reviews.

The notably low number of review articles found highlights the need for further theoretical studies, including bibliometric and bibliographic reviews, to examine the current scenario, the most discussed topics, and future ideas [21].

The VOSviewer software was used to select articles for analysis, identify the most commonly found terms and keywords, correlate them with the annual publication, and ascertain when each subject was discussed. The results can be observed in the clusters shown in Fig. 2.

In Fig. 2, it can be observed that the word clusters are interrelated, particularly 'cellulose masks'. Amnuakiet et al. (2011) were primary researchers in this application, experimenting with

methodologies to determine *in vivo* efficacy of a cellulose mask and evaluating the user satisfaction. The mask considerably increased skin moisture levels and the participants rated it as comfortable. The authors also reported good adherence of the mask to the skin, suggesting application of compounds for cutaneous treatments (e.g., whitening) [22]. Thus, in 2013 a cosmetic mask produced from cellulose was patented [23].

Additionally, Pacheco et al. (2017) performed the facial application of a bacterial cellulose mask containing two formulations, to analyze the mask performance. The release of the formulations by the biocellulose membranes indicated that it can be used as an appropriate system for cosmetic application. Furthermore, the preparation of the masks was simple, fast, and economical [19].

Perugini et al. (2018) noted the need to create a method to ensure stability and safety with respect to the manufacture and use of biocellulose masks, because a stability assessment is crucial for colloidal systems such as emulsions and suspensions. Therefore, they studied two biocellulose masks from different manufacturers and analyzed their organoleptic properties, pH, and viscosity. They also performed *in vivo* tests. They estimated that the shelf life for commercially stable and safe products, that is, bacterial cellulose masks, would be approximately 6 months. In conclusion, the authors consider bacterial cellulose to be a successful branch for the development of new cosmetics [24].

It should be noted that the term 'biocellulose mask' is the most current and originates from the union of other terms. The masks and their material produced by bacteria, being used mainly for the transmission of active compounds. It was observed that the results reported in the articles found are consistent regarding the potential application and satisfactory results obtained for the masks.

Table 1 shows the year and authors of the 18 selected articles, their title, journal name, and the number of citations in the literature.

In Table 1, although the journals of publication are diverse, they mainly deal with issues related to innovation and advances in materials engineering, biotechnology, and cosmetics. This could be associated with the pursuit of cosmetics innovations, including more sustainable production methods [12].

This sector has been exploring approaches, such as white biotechnology, with economic and ecological proposals to produce bioactive compounds that can replace synthetic compounds in the cosmetic industry while ensuring highly efficient skin treatments

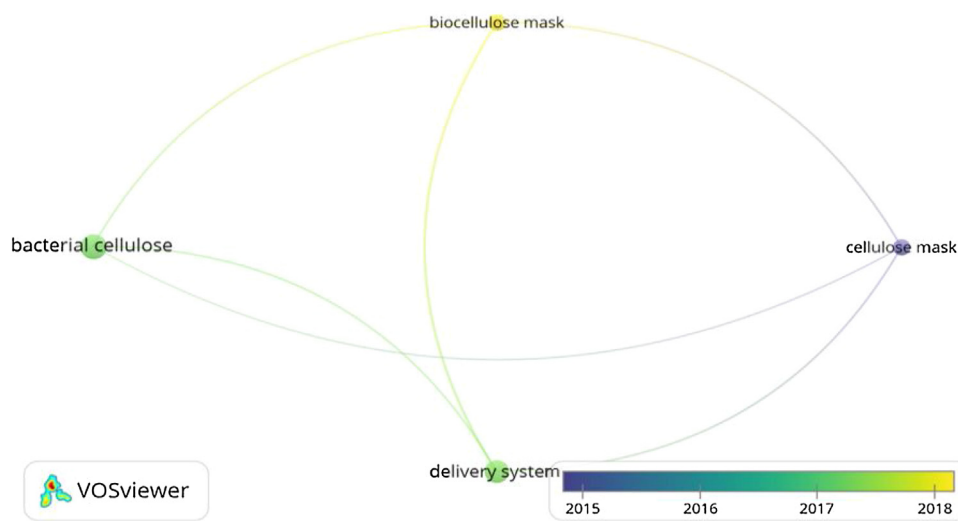


Fig. 2. Cluster formed by the keywords with the highest annual occurrence.

Table 1
Analysis of the 18 Articles Relating to Bacterial Cellulose in Cosmetics.

Year	Authors	Title and Journal	No. of Citations
2014	Almeida et al. [25]	Bacterial cellulose membranes as drug delivery systems: An <i>in vivo</i> skin compatibility study; <i>European Journal of Pharmaceutics and Biopharmaceutics</i>	111
2016	Gallegos et al. [13]	Bacterial cellulose: A sustainable source to develop value-added products – A review; <i>BioResources</i>	41
2011	Amnuaitkit et al. [22]	Effects of a cellulose mask synthesized by a bacterium on facial skin characteristics and user satisfaction; <i>Medical Devices Evidence and Research</i>	41
2016	Paximada et al. [26]	Effect of bacterial cellulose addition on physical properties of WPI emulsions. Comparison with common thickeners; <i>Food Hydrocolloids</i>	41
2018	Sharma et al. [8]	Commercial application of cellulose nano-composites: A review; <i>Biotechnology Reports</i>	36
2015	Numata et al. [27]	A slow-release system of bacterial cellulose gel and nanoparticles for hydrophobic active ingredients; <i>International Journal of Pharmaceutics</i>	25
2016	Stanislawska [14]	Bacterial nanocellulose as a microbiological derived nanomaterial; <i>Advances in Materials Science</i>	10
2017	Pacheco et al. [19]	Bacterial cellulose skin masks: Properties and sensory tests; <i>Journal of Cosmetic Dermatology</i>	9
2019	Morais et al. [29]	Anti-inflammatory and antioxidant nanostructured cellulose membranes loaded with phenolic-based ionic liquids for cutaneous application; <i>Carbohydrate Polymers</i> .	8
2017	Numata et al. [28]	Structural and mechanical characterization of bacterial cellulose–polyethylene glycol diacrylate composite gels; <i>Carbohydrate Polymers</i>	7
2019	Numata et al. [31]	Structural and rheological characterization of bacterial cellulose gels obtained from <i>Gluconacetobacter</i> genus; <i>Food Hydrocolloids</i>	5
2018	Chunshom et al. [30]	Dried-state bacterial cellulose (<i>Acetobacter xylinum</i>) and polyvinylalcohol-based hydrogel: An approach to a personal care material; <i>Journal of Science: Advanced Materials and Devices</i>	3
2020	Chantereau et al. [35]	Bacterial nanocellulose membranes loaded with vitamin B-based ionic liquids for dermal care applications; <i>Journal of Molecular Liquids</i> .	2
2018	Perugini et al. [24]	Biocellulose masks as delivery systems: A novel methodological approach to assure quality and safety; <i>Cosmetics</i>	2
2015	Oontawee et al. [33]	Physical properties of xyloglucan/bacterial cellulose composite film plasticized with glycerol; <i>Key Engineering Materials</i>	2
2016	Bayrakdar et al. [32]	Effect of semi-continuous operation mode parameters on bacterial cellulose and biomass production; <i>Cellulose Chemistry and Technology</i>	1
2020	Amorim, J. D. P. et al. [34]	BioMask, a polymer blend for treatment and healing of skin prone to acne; <i>Chem. Eng. Trans.</i>	1
2019	Perugini et al. [2]	<i>In vivo</i> evaluation of the effectiveness of biocellulose facial masks as active delivery systems to skin; <i>Journal of Cosmetic Dermatology</i>	0
2019	Amorim et al. [18]	Bacterial cellulose production using fruit residues as substrate to industrial application; <i>Chemical Engineering Transactions</i>	0
2020	Martins et al. [36]	A dry and fully dispersible bacterial cellulose formulation as a stabilizer for oil-in-water emulsions; <i>Carbohydrate Polymers</i> .	0

[7]. As an example, studies have verified the potential for the use of bacterial cellulose in cosmetic formulations to produce stable oil-in-water emulsions without harming the skin, using biocellulose as a biotechnological stabilizer [13]. Such studies may have led to the growing number of publications in journals on material innovations and biotechnology aimed at the cosmetics industry.

As seen in Table 1, the article entitled “Bacterial cellulose membranes as drug delivery systems: An *in vivo* skin compatibility study” is the most cited [25], with 111 citations. In this study the authors evaluated the potential for skin irritation with the application of bacterial cellulose membranes (with and without glycerin) and characterized the moisturizing effect on the skin. The

Table 2
Recommendations of the Authors for Future Studies Based on Previous Publications.

Authors	Recommendations for Future Studies
Almeida et al. (2014)	Further testing for the use of bacterial cellulose is believed to be necessary to confirm skin compatibility under normal use.
Sharma et al. (2019); Numata et al. (2017); Pacheco Guilherme et al. (2017); Numata et al. (2019); Chunshom et al. (2018); Numata et al. (2015) Perugini et al. (2018)	They mentioned that the bacterial cellulose has great potential for future research for use in the food, medical, pharmaceutical, and cosmetic fields; and the similar potential is noted for skin treatments and tissue repairing. Recent trends indicated that new cellulose-based bacterial materials are improving products encompassing the principles of green chemistry.
Gallegos et al. (2016)	To overcome current demands for green and value-added products, bacterial cellulose should remain the focus of future research.
Oontawee et al. (2015)	The combination of natural biodegradable polymers with natural active extracts can provide new biotechnological products that meet the needs of the world market, which seeks safe and ecological options.
Amorim et al. (2019)	To summarize, bacterial cellulose may be a promising substrate for the development of a new class of biotechnological cosmetics or cosmeceutical capable of providing many hydrophilic substances to the skin.
Martins et al. (2020) Chantereau et al. (2020) Amorim et al. (2020) Paximada et al. 2016	These biomaterials are innovative and biocompatible options for many industries. Bacterial cellulose is a good alternative for commonly used thickeners that can be used in future industrial applications.
Morais et al. 2019 Stanislawska 2016	Bacterial nano-cellulose is a material with potential to produce electroactive polymers due to the large amount of hydrogen bonds that stabilize the cellulose structure. Therefore, future tests need to be designed to gather further evidence.

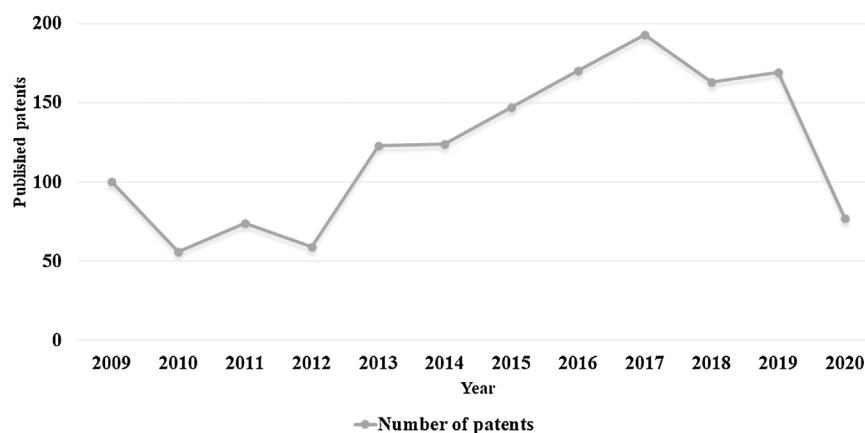


Fig. 3. Number of patents published between 2009-2020.

inclusion of glycerin increased the malleability and resulted in a moisturizing effect, making it clinically relevant for the treatment of dry skin diseases such as psoriasis and topical dermatitis.

Amorim et al. (2020) performed the addition of 2% propolis in bacterial cellulose facial masks. Natural propolis has an anti-inflammatory action and is excellent for treating skin acne. Added to the mask, it did not change its properties and structure of nanofibers, it then becomes a sustainable and safe option for a facial cosmetic [34]. Likewise, Chantereau et al. (2020) coupled vitamin B in bacterial cellulose facial masks, also for cosmetic purposes. As it is a very recent study, it presented few citations, but the results of the article are excellent, after all, the masks with the vitamin proved to be non-cytotoxic to human dermal cells, being a promising delivery method for facial rejuvenators [35].

As already mentioned, in addition to masks, there are studies that have shown the use of bacterial cellulose (BC) as a stabilizer for water and oil emulsions. Being a good resource in the cosmetic area. Martins et al. (2019) reported that due to intrinsic rheological and structural properties, BC may be applicable as a thickener, stabilizer and texture modifier. At a concentration of 0.50 %, the formulation was maintained for up to 90 days, without the need to add other types of chemical emulsifying agents. Proving total cellulose efficiency [36].

Three articles in this review have not been cited in the literature, possibly due to their recent publication.

Table 2 presents the recommendations for future studies based on the articles in Table 1.

Table 2 shows agreement among all authors on the future expectations regarding the applicability of bacterial cellulose. This biomaterial demonstrates numerous advantages in the field of food technology, paper, cosmetics, pharmaceuticals, the electronics industry and, importantly, in medicine. It can act as a thickener, form new polymers and biocomposites, be used as temporary skin, and in toxic waste filtration, among many other applications yet to be discovered [13,14].

Fig. 3 shows the number of patent publications between 2009 and 2020.

It should be noted that over the years, the number of publications has gradually increased. In 2020 there was a recent publication of the addition of bacterial cellulose in beautifying cosmetics, the bacterial cellulose ensured that the colored base came out more easily due to a dense network of a three-dimensional network structure formed by microfibers. Facilitating the cleaning and removal of the colored base from the face [37]. In 2019, Guo et al. patented a bacterial cellulose facial mask, made

from fermented banana peel, using a residue as a valuable resource in the production of cosmetic masks [38].

Jiong et al. (2018) developed a patent with the elaboration of a bacterial cellulose mask with hyaluronic acid and sericin, for cosmetic application. The mask demonstrated high moisturizing power for the skin, avoiding the loss of moisture from the mask and allowing excellent skin results [39].

4. Conclusion

Bacterial cellulose is being used in many areas of application and, consequently, is attracting attention in the cosmetics industry. As a result, this review showed that the number of publications and interest in this topic has increased. An important use of bacterial cellulose is in the production of cosmetic masks, mainly for the delivery of assets, and this material can also be used as an emulsion stabilizer and creams.

Although this study was limited to four databases, relevant articles were found, which provided an overview of the main characteristics of bacterial cellulose, focusing on the cosmetics area. In addition, as it is a biodegradable polymer, it offers biocompatibility, water retention capacity and low cost. These properties of cellulose will lead to new research publications in the near future.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.btre.2020.e00502>.

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