fermentation

Systematic Review

From Tea Fermentation to New Technologies: Multisectoral Applications of Kombucha SCOBY Through the Lens of *Methodi Ordinatio*

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Abstract

The Symbiotic Culture of Bacteria and Yeast (SCOBY) is a cellulose-based biofilm resulting from the fermentation of sweetened tea by a microbial consortium of acetic acid bacteria and yeasts. This study applies the *Methodi Ordinatio* technique to systematically identify, rank, and analyze the most relevant scientific publications on the applications of SCOBY. A comprehensive search in SCOPUS and Web of Science yielded 179 articles, after manual filtration. The InOrdinatio index, which combines citation count, publication year, and journal impact factor, was used for ranking to select a representative sample of the most important contributions (117 articles). The highest-ranked article scored 128.9, and the lowest 42.6. China led in scientific output (14.01%), followed by India (11.46%), the UK and USA (5.10% each), and Brazil (4.46%). The International Journal of Biological Macromolecules was the most frequently used journal for publications in this field. "Bacterial cellulose" was the most cited keyword (61 times), followed by "kombucha" (41) and "fermentation" (29). A consistent rise in publications has been observed over the past five years. Four main application areas were identified: bacterial cellulose (BC) (38%), biosustainable materials (28%), biomedical (17%), and food-related uses (17%). Most of the studies related to BC production (52%) searched for alternative substrates, and 18% focused on the isolation and identification of the most productive microorganisms within SCOBY. For biomedical applications, a unifying theme is the development of SCOBY-based materials with intrinsic antibacterial properties. These findings emphasize SCOBY's emerging role in sustainable innovation and circular economic frameworks.

Keywords: biotechnology; biofilm; bacterial cellulose; functional materials

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1. Introduction

SCOBY stands for Symbiotic Culture of Bacteria and Yeast, which is a cellulose-based material in the form of a biofilm formed during the fermentation of sweetened infusions of *Camellia sinensis* (commonly known as green or black tea), resulting in the production of kombucha, a sweet, effervescent beverage of growing global popularity [1]. This fermentation process is driven by a complex microbial consortium, predominantly composed of *Komagataeibacter xylinus*, *Gluconacetobacter oxydans*, and *Brettanomyces* spp., which operate in symbiosis: yeasts convert sugars into ethanol and organic acids, which are subsequently utilized by acetic acid bacteria to synthesize bacterial cellulose [2]. Within this system, the SCOBY not only functions as a metabolic interface but also acts as a protective structure, ensuring oxygen access and shielding the microbial community from environmental stressors such as UV radiation and pressure [3].

SCOBY is primarily composed of bacterial cellulose (BC), which has the same chemical formula as plant cellulose, $(C_6H_{10}O_5)_n$, consisting of long chains of β-glucose units linked through β-1,4-glycosidic bonds. At the molecular level, its biosynthesis is catalyzed by cellulose synthase complexes, which polymerize glucose residues derived from uridine diphosphoglucose (UDP-Glc) into β-1,4-glucan chains. These chains are further associated through intra- and intermolecular hydrogen bonding, resulting in crystalline cellulose I fibrils characterized by unidirectional polarity and exceptional tensile strength [4]. This structural arrangement endows BC with unique properties such as high crystallinity, hydrophilicity, biodegradability, and a broad potential for chemical modification.

The synthesis of BC begins with the extrusion of nanofibrils (~1.6 × 5.8 nm) by cells, which aggregate into approximately 46 elementary microfibrils. These microfibrils align side by side to form larger ribbon-like structures that continuously extend from the bacterial surface. The ribbons then interweave into a dense, three-dimensional network, giving rise to the characteristic bacterial cellulose (BC) pellicle [5].

According to Grand View Research, the global kombucha market was valued at USD 4.26 billion in 2024, and is projected to reach approximately USD 9.09 billion by 2030, growing at a compound annual growth rate (CAGR) of 13.5 % [6]. The growing commercial relevance of kombucha has attracted major multinational companies. For instance, Coca-Cola invested $20 million in the U.S. brand Health-Ade and acquired the Australian company Mojo, while Starbucks tested kombucha-based beverages through its Evolution Fresh product line. These initiatives illustrate how kombucha has evolved from a niche artisanal drink into a globally recognized functional beverage, highlighting the importance of exploring SCOBY applications beyond traditional uses [7]. Despite the expanding production of kombucha, SCOBY is frequently regarded as a low-value by-product [8]. However, it has unique properties, such as biocompatibility, mechanical strength, thermal stability, and structural purity, which make it a promising material for high-value applications in fields such as biomaterials [9–21], textiles [22–28], filtration systems, and environmental remediation [29–33]. This valorization potential aligns with circular economy strategies, which seek to transform industrial by-products into functional materials, thereby reducing waste and fostering sustainable production systems [34].

In parallel with the growing scientific and technological interest in SCOBY, the volume of academic publications has increased significantly in recent years. Consequently, researchers are now faced with an overwhelming volume of scientific literature, making it essential to carefully select and prioritize high-impact studies to compose a relevant and robust research portfolio [35,36]. To ensure the quality and relevance of bibliographic data, different systematic review methodologies have been proposed, such as the Cochrane Collaboration model [37] and the ProKnow-C approach [38], which provide structured strategies to minimize bias and guide the selection of relevant literature.

Considering these methodologies, the present study applies the *Methodi Ordinatio* proposed by Pagani et al. [39] to systematically identify, rank, and analyze the most relevant scientific publications related to SCOBY applications. This method combines journal impact factor, number of citations, and year of publication into a single index (InOrdinatio), providing a robust tool for selecting influential literature. Through this analysis, we aim to map the current state of SCOBY research and highlight its future potential in the food, biomedical, environmental, and materials science sectors, underscoring its role as a biosustainable solution within the context of circular economic development.

2. Materials and Methods

2.1. Systematic Mapping of Literature on Kombucha-Derived SCOBY

The systematic search for articles related to the use of SCOBY derived from kombucha fermentation was conducted using the *Methodi Ordinatio* for the selection of scientific articles [39], following the nine phases of this methodology (Figure 1). This review was conducted following the PRISMA 2020 guidelines for systematic reviews.

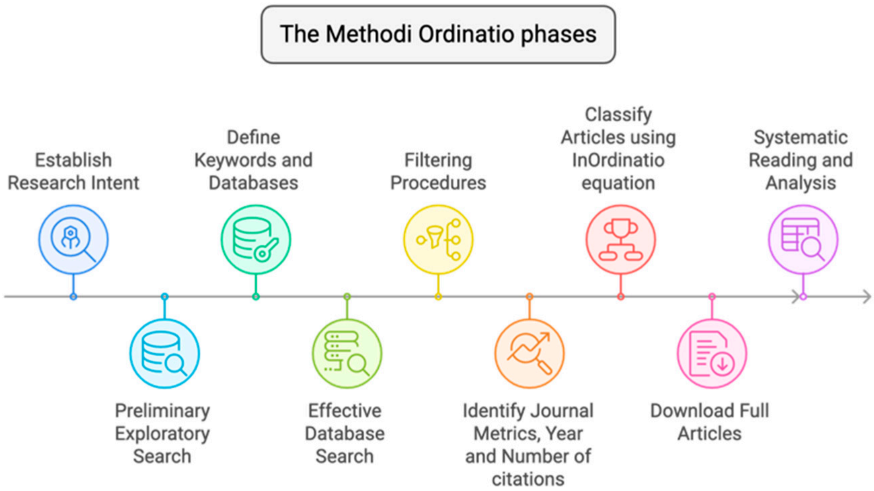

Figure 1. Flowchart of the *Methodi Ordinatio* phases for selecting and ranking scientific papers. Adapted from Pagani et al. [39].

Searches were performed in SCOPUS and Web of Science databases using combinations of the most relevant terms that was established in two keyword blocks (using the Boolean operators "OR" and "AND", as well as quotation marks and the asterisk wildcard character): Block 1 (kombucha OR "fermented tea") AND Block 2 (scoby OR biofilm OR *cellulose OR "acetobacter xylinum"), applied to titles, abstracts, and keywords. After duplicate removal and screening based on language and scope criteria, 794 articles were initially retrieved, and 179 were retained for evaluation (Figure 2).

The 179 articles were then ranked according to the *InOrdinatio* index, which integrates citation counts, journal impact factor, and publication year into a single score (Equation (1)) [39].

$$\text{InOrdinatio} = \text{Citation counts} + \text{Impact factor} + (10 \times \alpha) - (\alpha \times \text{Publication Age}) \quad (1)$$

in which Citations counts is the total number of citations the article has received according to the Scopus and Web Of Science databases, Impact factor is the JCR impact factor of the journal in which the article was published, α (alpha) is the weighting factor assigned by the researcher, ranging from 1 to 10, where a higher value ($\alpha = 10$) prioritizes more recent articles, and a lower value ($\alpha = 1$) prioritizes older articles, and Publication Age is calculated as the difference between the current year and the year of publication. An alpha value of 4 was adopted to strike a balance between citation count and publication recency. To ensure the inclusion of the most relevant studies, we selected the top 70% of articles based on their InOrdinatio ranking. As a result, the portfolio of this review consists of 117 selected papers.

The complete description of all nine phases of the *Methodi Ordinatio* is provided in the Supplementary Materials, together with the PRISMA checklist and flow diagram.

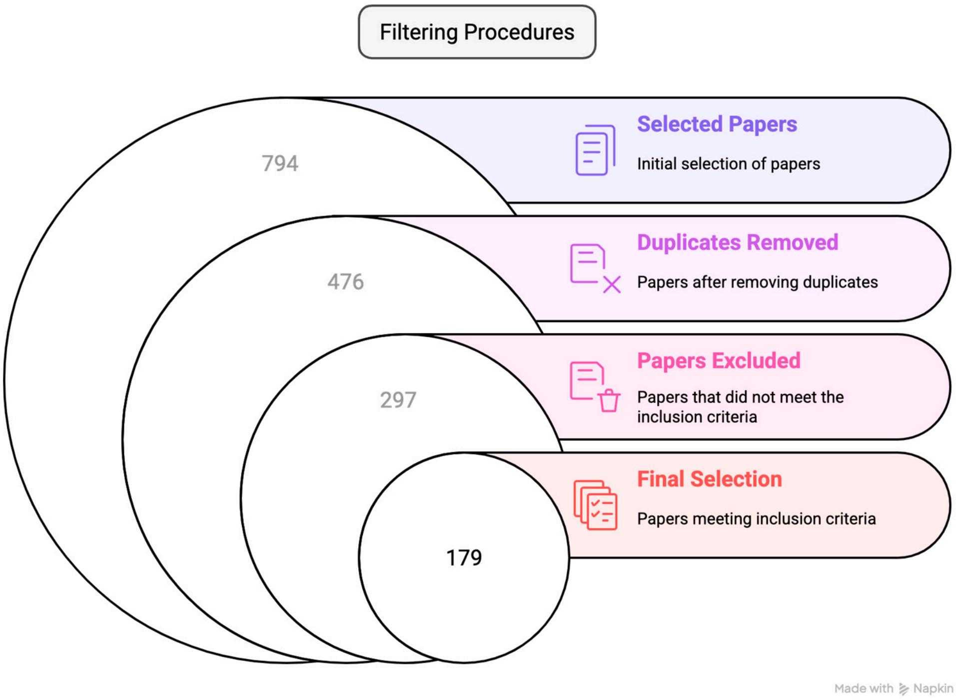

Figure 2. Graphical representation of the filtering procedure and results of the application of the *Methodi Ordinatio* for the theme "scientific advances and innovative applications involving kombucha-derived SCOBY".

2.2. Data Analysis

Data cataloging and analysis were carried out using standard Microsoft Excel spreadsheets. Additionally, VOSviewer software (version 1.6.20) was employed to analyze the collected data, such as keywords, to construct a social network map, providing insights into how clusters are structured within this field. Mendeley was used to organizing the references. The Rayyan platform was employed to organize the references, screen the studies, and remove duplicates.

3. Results

3.1. Methodi Ordinatio Analyses

In this review, from the 179 articles found on the subject of "scientific advances and innovative applications involving kombucha-derived SCOBY", 117 articles were selected to perform the analysis. The selection was based on the InOrdinatio index (Equation (1)). To assess representativeness, the InOrdinatio values of all papers with a score (179 papers) were summed, and the cumulative percentage of this total was calculated for each article, starting from the highest score (Figure 3). Notably, the 117 selected articles accounted for approximately 70% of the total InOrdinatio value, demonstrating that the chosen sample is highly representative of the most relevant literature on the topic.

The highest InOrdinatio score was 128.9 [22], while the lowest was 42.6 [28]. The 10 most relevant papers among the 117 selected for this review are presented in Table 1, which highlights the high number of citations received by the top 10 articles, with an average of 80 citations. It also underscores the relevance of the journals in which these papers were published, with an average impact factor of 4.7. The full classification can be found in the Supplementary Material (Table S1).

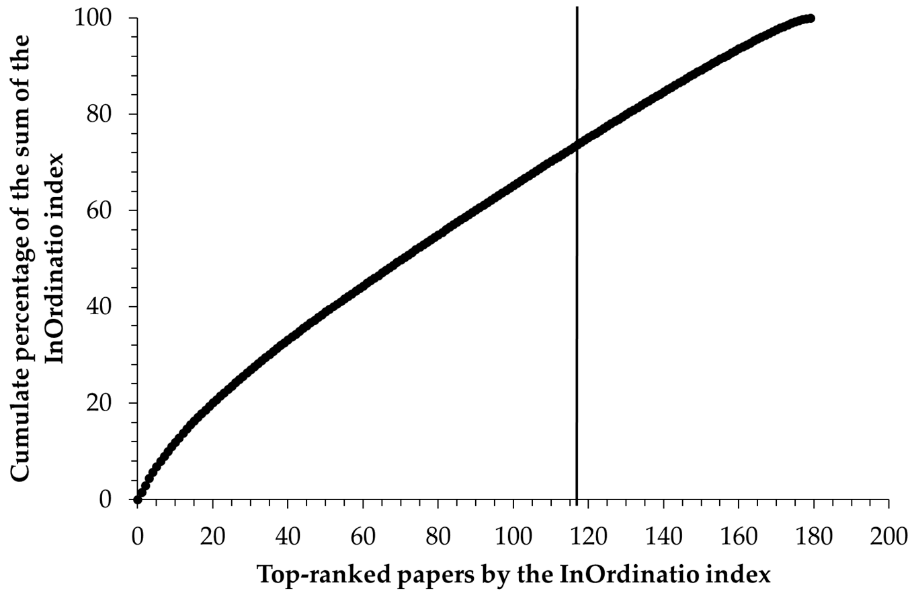

Figure 3. Cumulative InOrdinatio Score Highlighting the Representativeness of the Sample of articles related to scientific advances and innovative applications involving kombucha-derived SCOBY.

Table 1. Top ten scientific papers in the field of scientific advances and innovative applications involving SCOBY, derived from kombucha fermentation, according to the results of the *Methodi Ordinatio*.

Rank	Article Title	IF [1]	Citations	PA [2]	InOrdinatio	Ref.
1	Hydrogel bacterial cellulose: a path to improved materials for new eco-friendly textiles	4.9	100	4	128.9	[22]
2	Bacterial nanocellulose from side-streams of kombucha beverages production: Preparation and physical-chemical properties	4.7	111	7	127.7	[40]
3	Characterization of cellulose production by a *Gluconacetobacter xylinus* strain from Kombucha	2.3	130	16	108.3	[41]
4	*Komagataeibacter rhaeticus* grown in sugarcane molasses-supplemented culture medium as a strategy for enhancing bacterial cellulose production	5.6	81	6	102.6	[42]
5	Bacterial cellulose films production by Kombucha symbiotic community cultured on different herbal infusions	8.5	57	2	97.5	[43]
6	Biotransformation of fermented black tea into bacterial nanocellulose via symbiotic interplay of microorganisms	7.7	59	5	86.7	[44]
7	Fabrication of natural-origin antibacterial nanocellulose films using bio-extracts for potential use in biomedical industry	7.7	53	4	84.7	[45]
8	Pb(II) removal from synthetic wastewater using Kombucha Scoby and graphene oxide/Fe_3O_4	1.4	67	6	84.4	[32]
9	Kombucha bacterial cellulose for sustainable fashion	1	58	5	79	[23]
10	Kombucha-synthesized bacterial cellulose: Preparation, characterization, and biocompatibility evaluation	3.9	75	10	78.9	[46]

[1] IF—Impactor Factor, [2] PA—Paper Age.

It is important to note that the journal *International Journal of Biological Macromolecules* (impact factor 7.7) published two of the top 10 articles. Moreover, it was the most frequently occurring journal among the 117 articles analyzed, representing 6.6% of the total (8 occurrences) within a sample of 87 different journals, demonstrating its strong relevance to the research topic (Figure 4). It was followed by the journals *Cellulose* (impact factor 4.9) and *Polymers* (impact factor 4.7) in frequency, with both journals accounting for 5.79% (7 occurrences) each of the total samples.

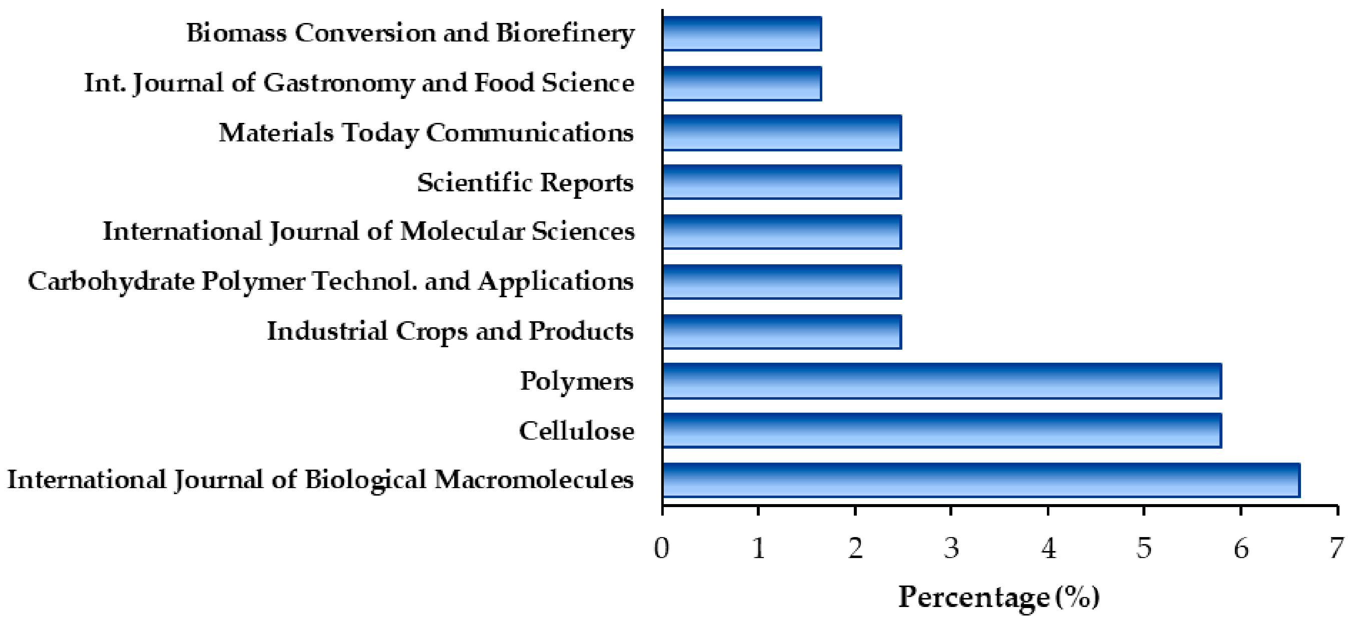

Figure 4. The ten most influential journals about scientific advances and innovative applications involving kombucha-derived SCOBY among the 117 selected papers.

3.2. Bibliometric Analysis

Among the 117 articles included in our sample, an exponential increase in scientific production related to the applications of SCOBY from kombucha was observed. This growth reflects that the interest in SCOBY is not only related to the production of kombucha itself, but also as a material with potential applications beyond its traditional use. A marked increase in publications was observed over the past four years (2020–2024), both among the 117 selected studies and within the total of 179 articles that met the inclusion criteria for this review (Figure 5). The earliest identified publication dates back to 2008 [41], and it is notably ranked among the top 10, according to the InOrdinatio index, due to its high number of citations. This outcome aligns with the weight given to citation count in the InOrdinatio equation, reflecting our intent to balance the inclusion of both recent studies and highly cited works.

In total, 39 countries participated in boosting scientific contributions on the perspectives of using SCOBY from kombucha, with 659 authors. Figure 6 shows the scientific contribution of each country, with China (14.01%) leading, followed by India (11.46%), and then the United Kingdom and the United States, both with 5.10%. Brazil is in fifth place with 4.46%. However, when we examine the individual number of authors per country (Figure 7), China and India remain in first and second place, but Brazil moves up to third. Additionally, other countries show a different level of participation when considering the total number of researchers. For instance, Romania moves from 14th to 4th place, while Iran advances from 8th to 5th position, as compared to the ranking presented in Figure 6. This difference may be attributed to the collaborative nature of scientific production in certain countries. Nations such as Brazil, Romania, and Iran, although ranking lower in total number of publications, demonstrate a higher number of contributing authors, suggesting a stronger presence in collaborative or multi-institutional research efforts. This pattern may also reflect larger research groups or broader participation in joint international studies.

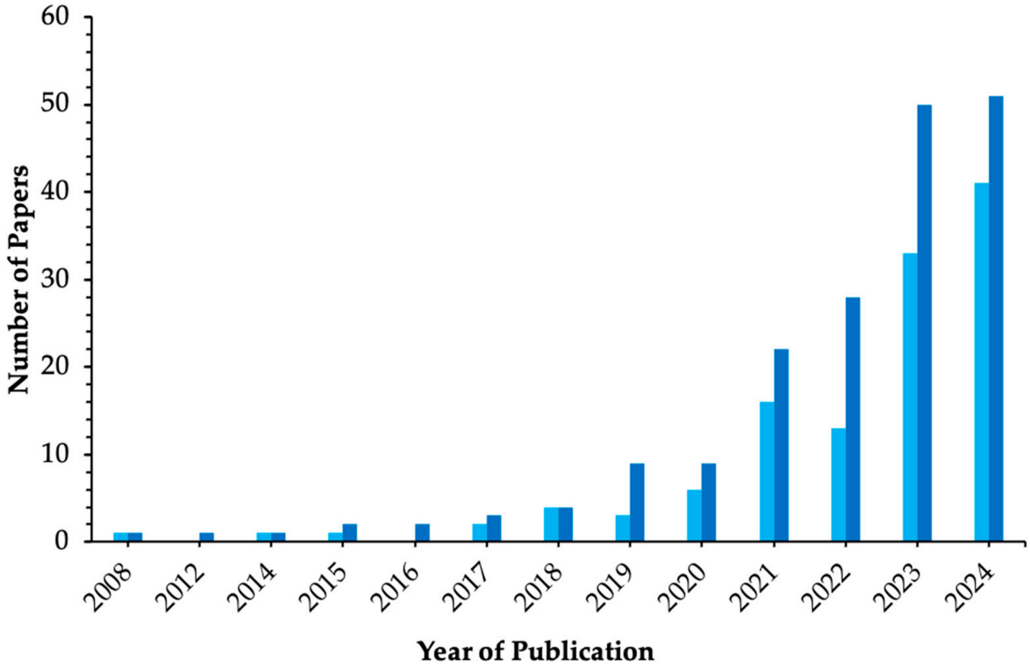

Figure 5. Number of papers published per year related to the "scientific advances and innovative applications involving kombucha-derived SCOBY", among the 117 selected articles (light blue bars) and among all 179 articles that met the inclusion criteria (dark blue bars).

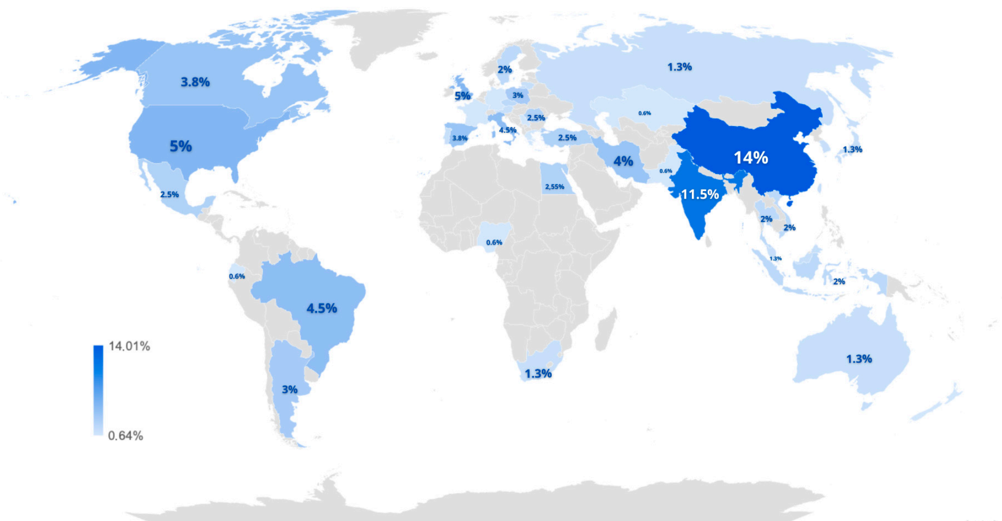

Figure 6. Countries' contribution to publications on the subject of "scientific advances and innovative applications involving kombucha-derived SCOBY" among the 117 selected papers.

The keywords from the 117 selected articles were analyzed, resulting in 709 distinct terms. Among them, 31 appeared at least five times and were used to form the clusters shown in Figure 8. The most frequently used keyword was "bacterial cellulose" (61 occurrences), followed by "kombucha" (41), "fermentation" (29), "tea" (14), and "nanocellulose" (10). Nanocellulose has gained attention due to its high purity and versatile properties, such as crystallinity, water holding capacity, chemical stability, and biological adaptability, applicable across various sectors [47]. Bacterial cellulose (BC) is the key component that gives SCOBY its structural characteristics, which is produced by bacteria as a survival strategy, facilitating access to oxygen and offering protection against UV radiation and hydrostatic pressure [48]. Figure 8 also highlights the green cluster, which includes the keywords "*Gluconacetobacter xylinus*" and "*Acetobacter xylinum*", the main bacterial species responsible for BC production. Additionally, it is evident that functional activities associated with bacterial cellulose, such as antimicrobial and antioxidant properties, are commonly studied in this context.

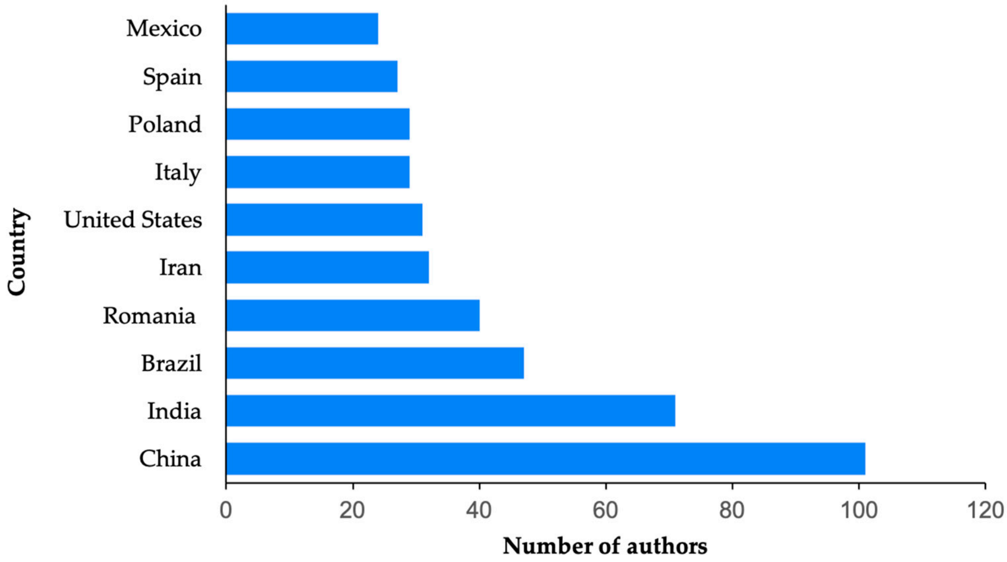

Figure 7. Countries' contribution based on the number of authors involved in scientific publications on "scientific advances and innovative applications involving kombucha-derived SCOBY" among the 117 selected articles.

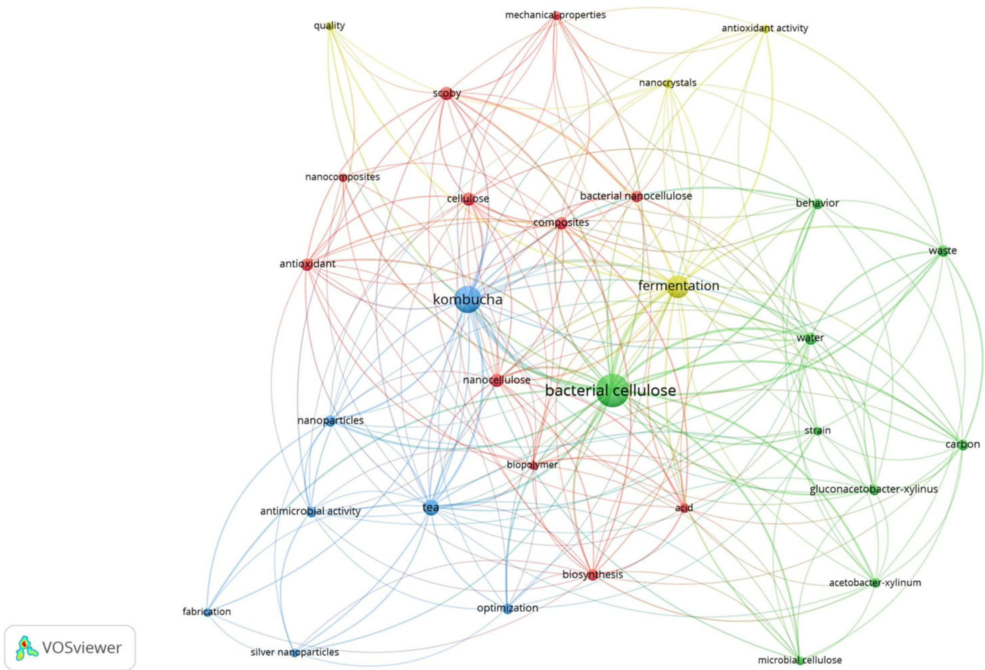

Figure 8. Keyword network map, from VOSviewer, of the 117 selected papers related to the scientific advances and innovative applications involving SCOBY, derived from kombucha fermentation.

3.3. SCOBY Applications

In a sample of 117 articles, four main application sectors for kombucha-derived SCOBY were identified (Figure 9). The most prominent was the production of bacterial cellulose (38%), with emphasis on optimizing production processes [44,47,49,50], developing more accessible and cost-effective cultivation methods [47], and exploring alternative substrates beyond sucrose and green/black tea to improve yield and sustainability [42,43,48,51–68]. Studies in this category also focused on microbial identification and isolation [41,51,69–73], as well as post-processing modifications such as the transformation of bacterial cellulose into nanocellulose to enhance its value and range of applications [40,74–77]. The application of SCOBY as a biosustainable material (28%) was the second most reported sector, highlighting its potential to replace synthetic products that pose risks to both the environment and human health. These innovations respond to current demands in areas such as electronics [78–85], textiles [78–85], water treatment [32,33,86–90], and plastic alternatives [10–14,91–93]. SCOBY was also explored in biomedical innovations (17%), including applications in wound healing [46,94–99], tissue engineering [46,95,99–101], dermocosmetics [102,103], and dental materials [104–107], due to its biocompatibility and structural versatility. Lastly, food sector applications (17%) extended beyond kombucha production, encompassing culinary uses [108–114], active packaging [92,93,115–119], and roles in Pickering emulsions and delivery systems [120–123].

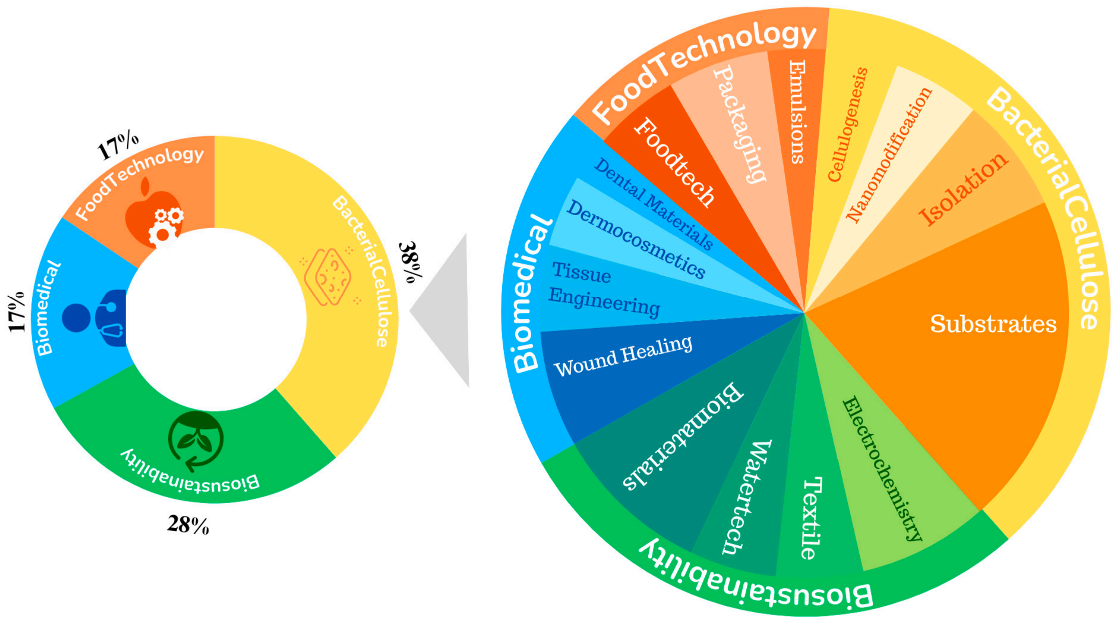

Figure 9. Main application sectors of kombucha-derived SCOBY based on 117 articles: bacterial cellulose production (38%), biosustainable uses (28%), biomedical applications (17%), and food technology innovations (17%).

3.3.1. Bacterial Cellulose

Among the 117 articles analyzed, 38% focused on the use of SCOBY for bacterial cellulose (BC) production. Within this group, the majority of the articles (52%) concentrated on the search for alternative substrates, for example, the paper ranked fourth in the InOrdinatio index (score: 102.6) that investigated bacterial cellulose production using different culture media, including agro-industrial residues, glucose, glucose supplemented with sugarcane molasses, and sugarcane molasses alone, highlighting the relevance of alternative substrates for sustainable production [42]. Approximately 18% of the cellulose-related studies focused on the isolation and identification of microorganisms within the

SCOBY, aiming to enhance production efficiency by selecting more productive microbial strains [41,51,69–73,124,125]. Another 14% explored the modification of bacterial cellulose, particularly through its transformation into nanofibers or nanocrystals, in order to expand its technological applicability [40,74–76]. Finally, 11% of the studies targeted the optimization of the production process, with the goal of improving yield and cultivation parameters [44,47,49,50]. In the analyzed papers, bacterial cellulose has been consistently described as a unique biopolymer, characterized by its nanofibrous morphology, as well as by its favorable viscoelasticity, mechanical strength, and moldability [125], high water-holding capacity [25], and remarkable purity, being inherently free of lignin, hemicelluloses, and other contaminants [44,53]. A recent techno-economic analysis of a kombucha-based BC production facility with an annual capacity of 60 tons estimated an initial investment of USD 13.72 million and annual operating costs of USD 3.8 million, with a payback period of 4.23 years, a return on investment (ROI) of 23.64%, and an internal rate of return (IRR) of 16.48%. The study also emphasized that increasing fermenter volume and implementing process automation could significantly reduce production costs, strengthening the case for industrial-scale feasibility under optimized conditions [49]. Regarding production methodology, Sharma et al. [47] identified the SIFB (Static Intermittent-Fed Batch) system as the most efficient cultivation strategy for bacterial nanocellulose production using SCOBY and black tea medium. This approach yielded significantly higher quantities of cellulose at lower cost when compared to other systems, particularly outperforming the rotary disk bioreactor, which demonstrated minimal production under the same conditions.

Alternative Carbon Sources for SCOBY BC Production

Among the 117 articles evaluated, 21 studies addressed the use of alternative substrates for bacterial cellulose production (Table 2). Notably, two of these articles are included in the top 10 according to the InOrdinatio index [42,43], as shown in Table 1. Within this group of 22 articles, the journals *Industrial Crops and Products*, *Cellulose*, and the *International Journal of Biological Macromolecules* stand out in terms of relevance, each contributing more than one article to the list. The conventional production of BC using green or black tea with sucrose, as used in kombucha-based systems, poses limitations in terms of cost, scalability, and sustainability. The culture medium is the principal cost in the BC production [67]. In this sense, a comparative overview of BC production using various substrate types is presented in Table 2. Overall, agro-industrial byproducts, including sugarcane molasses, corncob and bagasse hydrolysates, soy whey, and acerola waste, have been widely explored as sustainable and low-cost alternatives to conventional synthetic media, like Hestrin–Schramm (HS) [42,51,57–59,126]. Notably, the use of Iranian Nabat industry waste under stirred submerged fermentation conditions yielded up to 45.5 g/L of BC in just 7 days [66]. Among herbal infusion-based media supplemented with sucrose, yerba mate (19.4 g/L) [48] and green tea with dextrose (11.19 g/L) [54], stood out, reinforcing the potential of kombucha-like substrates for BC biosynthesis. Another promising approach involved the use of food waste, such as diluted acid hydrolysates of various stale bread types, which achieved yields ranging from 1.55 to 8.75 g/L after 14 days of static fermentation [63]. Most studies employed static fermentation [42,43,48,52–54,57–59,62,126]. However, some experiments used continuous stirred fermentation, which, in specific cases, significantly enhanced BC yields [51,66]. Fermentation time varied between 6 and 21 days, with the optimal values depending on the type of raw material and microbial strain used. This survey highlights the potential of valorizing agro-industrial and food residues as viable media for BC production, supporting the principles of the circular economy while reducing production costs and contributing to the sustainability of biotechnological processes.

Table 2. Summary of bacterial cellulose (BC) production using different raw materials categorized by raw material/substrate type, cultivation method, and BC yield.

Ranking	Raw Material Type	Raw Material/Substrate	Cultivation Method	BC Production (g/L)	Ref.
4	Agro-Industrial residue	Glucose Glucose + Sugarcane molassesSugarcane molasses	Static	2.27 g/L 4.01 g/L 1.9 g/L 10 days	[42]
5	Herbal Infusion + carbon source	Black tea + sucrose green tea + sucrose yerba mate + sucrose lavender + sucrose oregano + sucrose fennel + sucrose	Static	10.3 g/L 3.3 g/L 6.9 g/L 4.5 g/L 3.6 g/L 2.9 g/L 21 days	[43]
14	Agro-Industrial residue	Corncob enzymatic hydrolysate Sugarcane bagasse enzymatic hydrolysate	Continuous stirred agitation	1.6 g/L 1.2 g/L 7 days	[51]
27	Domestic residue	kitchen waste enzymatic hydrolysate	Static	4.76 g/L 10 days	[52]
34	Agro-Industrial residue + tea	Apple waste and tea byproducts	Static	0.8 g/L 7 days	[126]
40	Herbal Infusion + carbon source	Green Tea + Dextrose	Static	11.19 g/L 15 days	[54]
47	Herbal Infusion + carbon source	Yerba mate + sucrose	Static	19.4 g/L 21 days	[48]
49	Agro-Industrial residue + Tea	Tea + Banana Leaf Extract	Static	55 g/L 21 days	[56]
51	Agro-Industrial residue	Tofu soy whey + sucrose	Static	42 g/L 11 days	[58]
52	Agro-Industrial residue	Acerola Industrial Waste	Static	2.3 g/L 12 days	[57]
59	Agro-Industrial residue	Miscanthus enzymatic hydrolysate Oat hulls enzymatic hydrolysate	Static	0.88 g/L 1.03 g/L 14 days	[53]
70	Agro-Industrial residue	Soybean whey Soybean hydrolysate	Static	0.51 g/L 1 g/L 6 days	[59]
74	Fermentable agro-industrial wastewater + carbon source	Yellow wine wastewater + Fructose Corn Syrup	Static	16.5 g/L 7 days	[62]
75	Food Waste	Dilute acid hydrolysates of different bread wastes	Static	1.55 g/L–8.75 g/L 14 days	[63]
104	Agro-Industrial residue	Iranian Nabat Industry Waste	Continuous stirred agitation	45.5 g/L 7 days	[66]
107	Synthetic lab medium Agricultural nutrient solution + carbon source	Yeast Nitrogen Base + glucose NPK fertilizer solution + glucose	Static	8 g/L 8.8 g/L 17 days	[67]

SCOBY Microbial Isolation

In the analysis of 117 papers included in this review, eight studies specifically evaluated the yield of bacterial cellulose (BC) produced by strains isolated from kombucha [41,51,69–73,124,125]. Collectively, more than twelve distinct microbial strains and consortia were identified and cultivated for BC production. These microbial isolation studies represented approximately 9% of the total InOrdinatio score, with individual values ranging from a maximum of 108.3 to a minimum of 49.2. The isolation of microbial strains aims to optimize BC production. This is exemplified by the study of China et al. [71], which addressed BC yield variability linked to genotypic differences. The authors investigated the genetic diversity among *Komagataeibacter* strains and demonstrated that genetic variability has a strong influence on cellulose production. Most isolates were identified as *K. xylinus*, while one strain (K2G44) showed divergence. Reported BC yields ranged from 0.59 g/L (K2G36) to 23 g/L (reference strain K2G30). In the data collection of the eight analyzed articles [41,51,69–73,124,125], the productivity of each strain was registered and the differences between strains are illustrated in Figure 10. Li et al. [73] reported that *Komagataeibacter hansenii* JR-02 exhibited a 166% increase in BC yield under static cultivation compared to shaking conditions (180 rpm). In contrast, Zhang et al. [69] reported a modest ~10% increase in BC yield under shaking compared to static cultivation for *Gluconacetobacter xylinus* ZHCJ618. Similarly, Nguyen et al. [41] found no significant difference between static and shaking conditions but observed higher yields when using green tea medium (~0.20 g/L) compared to black tea medium (~0.14 g/L). Avcioğlu et al. [124] differed from most studies that focused solely on cellulose-producing bacteria, as they followed the logic of kombucha symbiosis, demonstrating that the co-culture of bacteria and yeasts (*Komagataeibacter saccharivorans* LN886705, *Brettanomyces bruxellensis* MH393498, and *Brettanomyces anomalus* KY103303) facilitated cellulose production. Under optimized conditions (1% black tea, 6% glucose, pH 6, 30 °C, 10 days, static cultivation), BC yield reached 18.68 g/L, representing a 306% increase compared to Hestrin–Schramm medium (4.59 g/L), with a 29.74% cost reduction. In conclusion, the reviewed studies demonstrate that strain selection, cultivation method, and medium composition are critical determinants of BC yield. Optimizing these factors can substantially enhance productivity and broaden the applicability of bacterial cellulose.

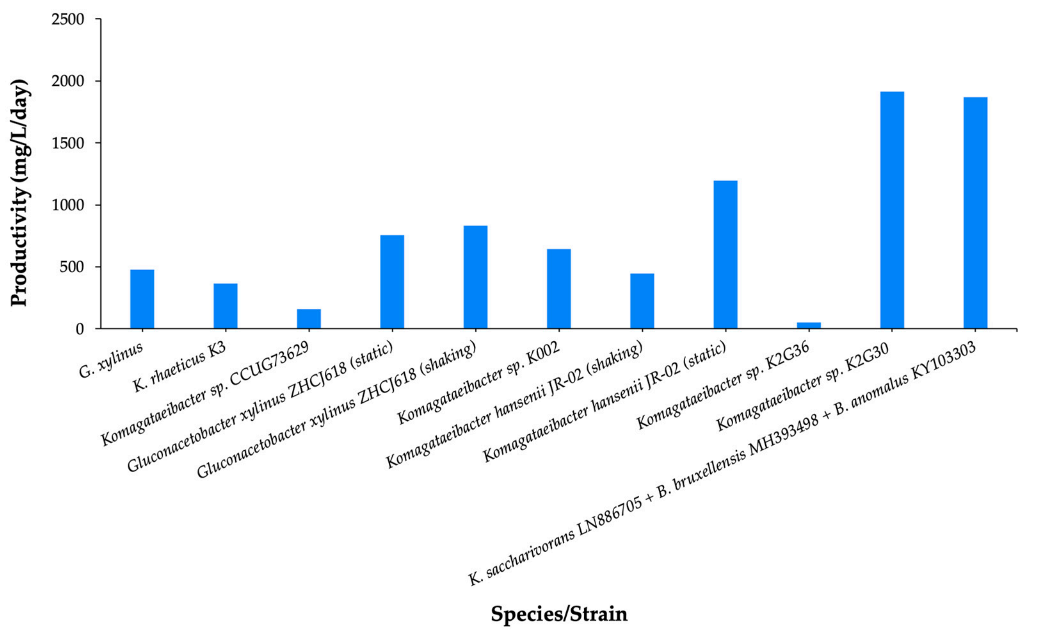

Figure 10. Productivity of bacterial cellulose by SCOBY-derived strains, according to data found in the selected articles [41,51,69–73,124,125] related to the isolation of microbial strains from Kombucha derived SCOBY.

Nanomodification and Functionalization of SCOBY

The nanomodification and functionalization of kombucha-derived BC significantly expand its potential applications. Six papers addressed methodologies aimed at enhancing the intrinsic properties of BC, together accounting for an InOrdinatio score of 379, which represents approximately 6% of the total [40,74–77,127]. Among these, *Dima* et al. [40] ranked second overall, with a score of 127, the highest within this topic, while *Mauro* et al. [77] presented the lowest score (43.7). The reported modifications mainly target chemical purification, approaches to achieve the nanoscale, and strategies to enhance both the structural and functional properties of BC. To analyze purification strategies, Dima et al. [40] applied alkaline treatments with 1 M and 4 M NaOH, achieving the removal of up to 97% of impurities and increasing crystallinity from 37% to 87%. Complementarily, Sederavičiūtė, Bekampienė, and Domskienė [74] reported that low-impact pretreatments with water or 0.5% NaOH enhanced crystallinity from 29% to 47% within 8 h, while also improving thermal stability and reducing amorphous regions, as confirmed by FTIR (Fourier Transform Infrared Spectroscopy) and XRD (X-Ray Diffraction) analyses [74]. Non-conventional approaches have been explored to enhance SCOBY-derived bacterial cellulose properties. Gamma irradiation, microfluidization, and different drying methods significantly influenced crystallinity, particle size, and mechanical performance, while functionalization strategies such as Suzuki coupling and boronic acid derivatives improved surface properties, particularly hydrophobicity, expanding potential applications in biomaterials, packaging, and food systems [40,75,76,127]. For example, Day et al. [69] performed a comparative analysis of microwave, hot air, and shade drying methods, reporting significant impacts on the properties of BC, such as water absorption, rehydration capacity, surface color, and mechanical integrity. The highest crystallinity value (78.44%) was obtained in samples dried in a hot air oven at 50 °C. Furthermore, the drying kinetics were most accurately described by the page and parabolic models under the evaluated conditions.

Together, these findings underscore the importance of carefully selecting purification, drying, and functionalization methods to unlock the full technological potential of kombucha-derived bacterial cellulose in advanced material science and industrial applications.

3.3.2. SCOBY as a Biosustainable Material

Among the 117 selected articles, approximately 28% explored the use of SCOBY as a biosustainable material, emphasizing its relevance as a renewable alternative aligned with circular economy principles. These studies were primarily distributed across four key sectors: biomaterials, with applications ranging from edible films to biodegradable composites [9–21]; electrochemical applications, including its integration into biosensors, conductive membranes, and supercapacitors [78–85]; textile innovations [22–28], focusing on the development of eco-friendly, breathable fabrics aimed at reducing microplastic pollution; and water treatment, which deals with SCOBY and its derivatives as effective bioadsorbents for removing contaminants such as dyes and heavy metals; textile innovations [22–28].

SCOBY as a Biomaterial

A remarkable diversity of functional biomaterials can be derived from SCOBY, with applications spanning a wide range of technological sectors and offering strong ecological appeal. In this portfolio, 12 papers specifically address the use of SCOBY as a biomaterial, accumulating a combined *InOrdinatio* score of 543, which represents approximately 6.7% of the total score [10–21]. Notably, 10 of these articles were published within the last two years, underscoring the growing scientific interest and contemporaneity of this field. These biomaterials demonstrate particularly promising applications, SCOBY-derived cellulose can be tailored through chemical or physical modifications, for instance by functionalization with lignocellulosic derivatives or nanomaterials to enhance its mechanical strength [20], or by subjecting it to acid hydrolysis, which increases porosity and crystallinity while yielding nanofiber-enriched aerogels with improved stability [19] and innovative self-cooling composites, achieving surface temperature reductions of up to 3.8 °C [21]. Despite these advances, one of the most intensively explored directions remains the use of SCOBY as a biodegradable alternative to petroleum-based plastics in packaging, representing 70% of the 13 articles analyzed. However, a persistent challenge is to improve the mechanical strength of these materials. Nonetheless, the intrinsic incompatibility between the hydrophilic nanofibrils of bacterial cellulose and hydrophobic polymer matrices, such as polylactic acid (PLA), limits uniform dispersion and hinders composite performance [10,12]. Innovative strategies have been developed to improve the incorporation of SCOBY-derived cellulose into polymers. Examples include PLA and PMMA composites with enhanced thermal stability, rigidity, and homogeneity, as well as multifunctional bionanocomposites combining cellulose with nanoparticles and conductive polymers, which demonstrated improved mechanical, antimicrobial, and electrical properties. Emerging tools such as the Vortex Fluidic Device (VFD) further enhance structural reorganization and functionality of these materials [10–12,15,17]. Chong et al. [14] demonstrated that enzyme etching prior to chemical treatment enhances the surface area and functional properties of kombucha BC films, facilitating condensation reactions between surface hydroxyl groups and silane-modified cardanol—an industrial byproduct from the cashew-nut industry—thereby rendering the KBC surface hydrophobic. Taken together, these findings demonstrate the remarkable versatility of kombucha-derived bacterial cellulose as a renewable platform for the development of advanced, eco-friendly materials. Notably, bacterial cellulose produced from coffee kombucha has shown high biodegradability in soil, with approximately 75% decomposition within eight weeks, confirming its environmental compatibility and reinforcing its value for sustainable end-of-life scenarios [12,13]. Continued research into processing methods, functionalization strategies, and compatibility with industrial polymers will be essential to ensure its full potential in sustainable material science.

SCOBY for Electrochemistry

From the total of 117 studies analyzed, 8 specifically address electrochemical applications, representing approximately 6.8% [78–85]. This subset underscores the versatility of SCOBY-derived bacterial cellulose, which has emerged as a promising material not only in food and biomedical innovations but also in addressing contemporary challenges in electrochemical energy storage and sensing. In light of the growing global energy demand and the urgent call for sustainable and efficient technologies, the development of alternative, renewable materials has become increasingly critical. Within this context, SCOBY-based materials stand out as a viable platform for the fabrication of supercapacitors, biosensors, and electroactive devices. A notable contribution in this field is the study by Dai et al. [81], ranked 53rd in the overall InOrdinatio index, which presented one of the approaches in the electrochemical category. The authors proposed the synthesis of supercapacitor electrodes using kombucha-derived SCOBY as a carbonaceous precursor, activated in situ with 1–5% KOH and carbonized at 700 °C. The resulting material exhibited a hierarchical porous structure, with high specific surface area and a specific high capacitance, surpassing many conventional biomass-derived carbons [81]. Complementary studies reinforce this potential. Likewise, Nikolaidou et al. [80] reported the functionalization of kombucha mats with graphene and zeolite nanoparticles, enhancing their conductivity, capacitance, and mechanical sensitivity under compression, while exhibiting refractive responses [80]. In a separate investigation, Adamatzky [78] analyzed the spiking electrical activity of living kombucha mats under chemical and mechanical stimuli, suggesting their applicability in biosensing and unconventional bioelectronics [82]. Together, these studies highlight the strategic relevance of SCOBY in enabling eco-friendly electrochemical platforms, from high-performance capacitors to living biosensors, aligning with broader goals in sustainability, circular economy, and smart materials. As research advances, the multifunctionality, renewability, and tunable electrochemical properties of SCOBY-derived systems position them as a compelling solution for the next generation of energy and sensing technologies.

Textile Uses of SCOBY

Among the 117 papers analyzed, only 6% focus on the use of SCOBY textile applications [22–28]. This is particularly relevant given the growing concern over microplastic pollution, with the textile industry being a significant contributor to this issue. The focus is not only on the disposal of clothing but also on the synthetic fibers, which are non-biodegradable and often released into oceans, accumulating in both human and animal organisms [128]. A key study ranked 1st in this review [22], explores the modification of Kombucha-derived BC to improve its suitability for textile applications (Figure 11). The study focuses on the creation of a bacterial cellulose hydrogel by introducing glycerol, which significantly enhances the mechanical properties and flexibility of the Kombucha BC. This modification addresses the primary challenges associated with the raw material, including its brittleness and poor water resistance.

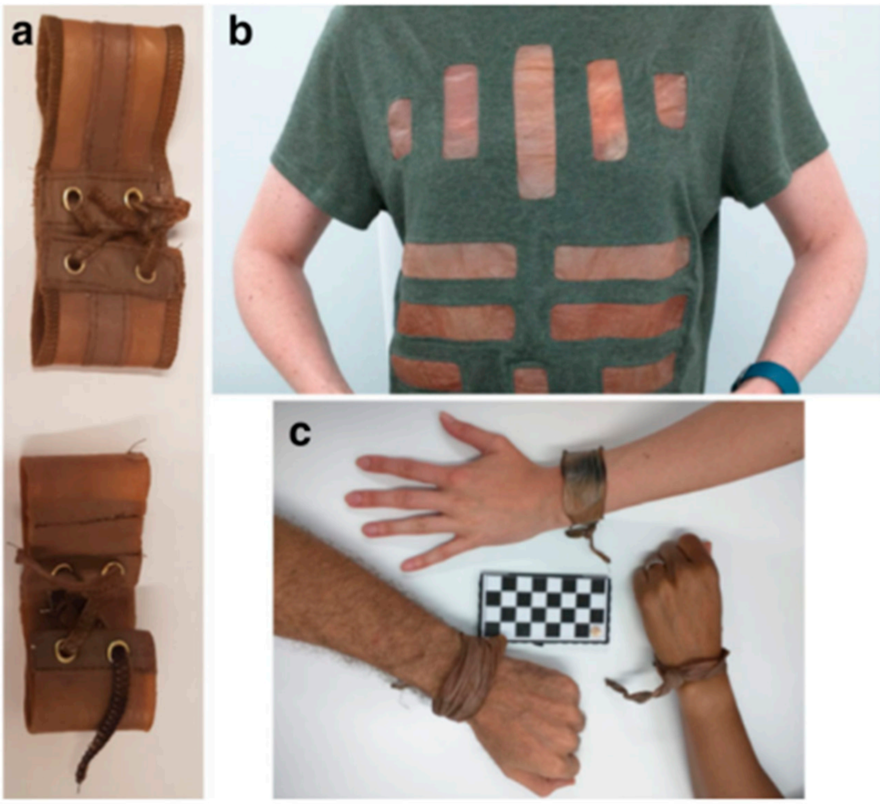

Figure 11. Photographs of the wristband, day 1 (**a**) and day 7 (**c**). T-shirt with sewn in cellulose-based coated fabric (**b**). Reproduced from Kaminski et al. [22], under the terms of the Creative Commons CC BY license (https://creativecommons.org/licenses/by/4.0/).

The main efforts in research in this area focus on solving the principal problems in the use of SCOBY as a textile material, such as color issues due to melanoidins, unpleasant odors from fermentation residues, brittleness, water resistance, and low mechanical strength. A significant chemical improvement was reported in 5 out of 7 articles, which represents

71.4% of the research papers reviewed, highlighting a clear trend toward functionalization for practical, sustainable textile use [22,24–27].

SCOBY in Water Treatment

The growing scarcity of potable water and the presence of toxic contaminants represent critical challenges to public health and environmental sustainability. In this context, 8 papers [9,29–33] evidence SCOBY as a promising material for key technologies traditionally developed from polymeric compounds, representing 6.8% of the 117 articles analyzed. Within this group, the highest InOrdinatio score is 84 [32], while the minimum is 43 [87]. SCOBY-derived bacterial cellulose has shown great potential in water treatment due to its eco-friendly and circular economy characteristics. Applications include aerogels for oil spill remediation, highly efficient bioadsorbents for heavy metals and dyes, and biochars produced with microalgae for pollutant removal. Functional composites, such as those with UiO-66 particles, further enhance dye adsorption, while bioflocculants from SCOBY-associated yeasts reduce COD and BOD and can generate antimicrobial nanoparticles. Additionally, living filtration membranes (LFMs) exhibit high efficiency in removing nanometric particles, self-healing capacity, antibacterial activity, and reduced biofouling compared to synthetic membranes, highlighting their promise for sustainable wastewater treatment [9,32,33,86–90]. In summary, the integration of sustainable technologies—including in situ SCOBY, SCOBY-derived biochar combined with microalgae, MOF-based adsorption, bioflocculation, and living filtration membranes—offers a promising strategy to tackle complex challenges such as pollutant toxicity, environmental degradation, and limited access to clean water (Figure 12).

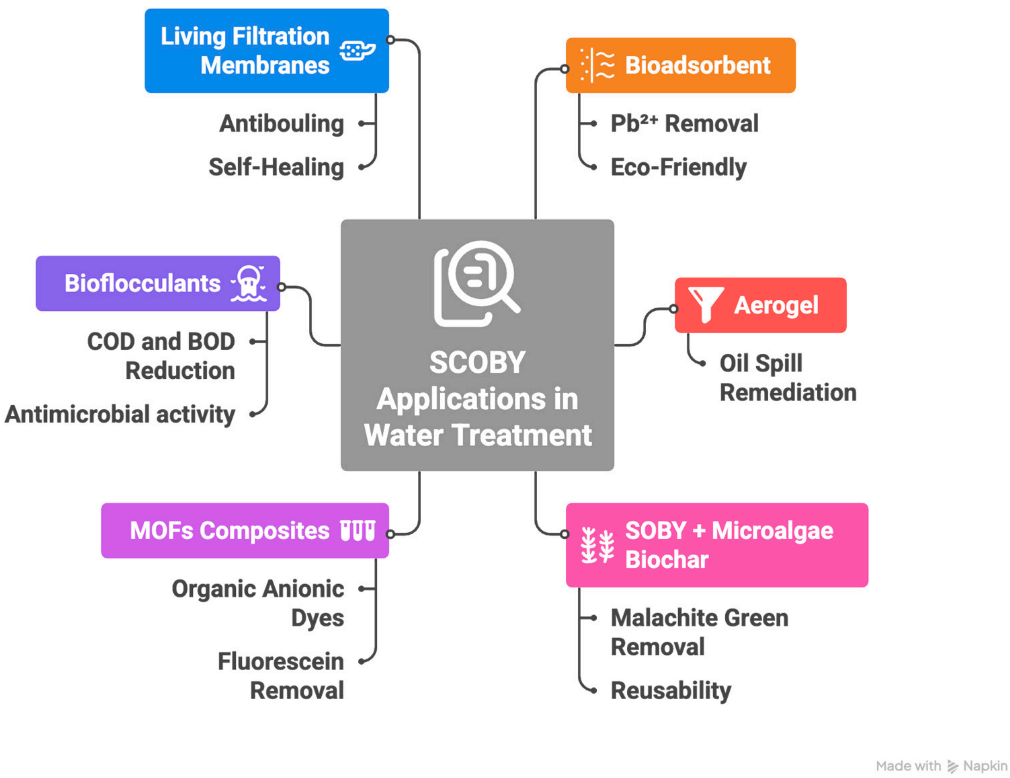

Figure 12. Sustainable water treatment with SCOBY-Based Technologies found in the selected articles related to the applications of Kombucha-derived SCOBY.

The use of natural, biodegradable, and widely available materials like kombucha-derived SCOBY highlights the potential of these approaches to support advances in bioeconomy and sustainable environmental management.

3.3.3. Biomedical

Among the 117 articles analyzed, 19 (approximately 16.2%) focused on biomedical applications of SCOBY-derived materials. Within this subset, two studies were ranked in the top 10 of the InOrdinatio index: "Fabrication of natural-origin antibacterial nanocellulose films using bio-extracts for potential use in biomedical industry" [45] (ranked 7th), and "Kombucha-synthesized bacterial cellulose: Preparation, characterization, and biocompatibility evaluation" (ranked 10th) [46]. These findings highlight the scientific relevance and novelty of biomedical applications. Within this subset, four main functional categories emerged as innovative areas: tissue engineering (5.1%) [46,95,100,101,106,129], wound healing (2.6%) [94,97,130], dental materials (2.6%) [105–107] and dermocosmetics (1.7%) [102,103]. Notably, a unifying theme across these applications is the development of materials with intrinsic antibacterial properties. This focus has become increasingly relevant in light of the growing incidence of infections caused by multidrug-resistant bacteria, which severely compromise treatment efficacy and reduce patient survival rates. In this context, numerous studies have proposed innovative alternatives for antibacterial materials that do not rely on antibiotics. Antibacterial activity was primarily achieved through the functionalization of SCOBY with various plant-based extracts, notably phytocompounds from *Terminalia arjuna* [45], or via incorporation of zinc oxide nanoparticles (ZnO NPs) [96], hydroxyapatite/titanium dioxide nanocomposites (HAp/TiO_2) [131], and gold nanoparticle (Au-NP)-functionalized chitosan-bacterial cellulose composites (Au-CBC) [98] synthesized by both immersion and in situ methods. These modified SCOBY-based materials demonstrated activity against *Staphylococcus aureus* [45,96,131], *Escherichia coli* [45,96,131], *Pseudomonas aeruginosa* [96], *Proteus mirabilis*, *Candida albicans* [131] and *Saccharomyces* spp. [98] suggesting strong potential for application in environments at high risk of microbial proliferation, such as medical devices and hospital surfaces.

SCOBY for Wound Healing

SCOBY-derived BC has emerged as a promising biopolymer for advanced wound dressings due to its biocompatibility, moisture retention, and adaptability [94,97,130]. Studies have demonstrated its efficacy when combined with bioactive agents. For instance, BC:HC (hydrolyzed collagen) films coated with chitosan showed improved mechanical strength and antibacterial activity against *S. aureus*, while enabling controlled release and stability of ascorbic acid [130]. A novel approach integrated kombucha microbial communities into a thermoresponsive Pluronic F127 matrix, forming a living gel capable of producing antimicrobial compounds at the wound site. This gel outperformed commercial treatments in infection control and tissue regeneration in multidrug-resistant models [94]. Additionally, BC membranes coated with *Pistacia atlantica* oil demonstrated anti-inflammatory effects and accelerated wound healing in burn models, reinforcing the potential of plant-enriched biomaterials for wound care [97]. These advances highlight the multifunctionality and sustainability of SCOBY-based materials in next-generation wound healing applications.

SCOBY in Tissue Engineering

Kombucha BC exhibits highly favorable properties for cytocompatibility, establishing itself as a promising biomaterial for tissue engineering applications. These characteristics have been confirmed in several studies included in this review [46,95,100,101,106,129]. Cell viability and adhesion were observed in fibroblasts cultured on Kombucha BC modified through partial acid hydrolysis for 3D bioprinting, as well as on Kombucha BC composites functionalized with chitosan and gold nanoparticles (CBC-Au), in which the cell lines demonstrated excellent adhesion, proliferation, and near-complete confluence [95,101,129]. Additionally, promising strategies have emerged in vascular, neural, and bone tissue engineering. Bacterial nanocellulose (BNC) tubes produced in bioreactors showed adequate mechanical properties and potential for use as vascular grafts in biomedical applications [100]. In neural tissue engineering, in vitro studies using Schwann cells and in vivo experiments in rats demonstrated that SCOBY-derived BNC had excellent biocompatibility and did not induce hematological or histological toxicity [46]. In bone regeneration, a nanocellulose-based composite coated with hydroxyapatite, synthesized via a biomimetic approach using *Serratia marcescens*, revealed a stable structure, low crystallinity, and ion substitutions resembling natural bone tissue, supporting its application as a biomaterial for bone tissue engineering [106]. Altogether, these studies exemplify the innovative and sustainable approaches being employed to harness the structural and biological versatility of SCOBY-derived materials for tissue engineering purposes, spanning applications from bioprintable inks to scaffolds for bone, nerve, and vascular regeneration.

SCOBY in Dermocosmetics

The growing demand for sustainable cosmetics is driving the use of natural ingredients and agro-industrial byproducts that combine functionality, biodegradability, and ecological appeal. Fermentation is widely recognized for its ability to enhance the bioactive compound content of plant extracts, including polyphenols, vitamins, organic acids, and peptides. The SCOBY from kombucha fermentation has been shown to produce a wide range of metabolites with antioxidant and antimicrobial properties. Studies report significant increases in theaflavins (~88.6%), epicatechin (~150%), and epigallocatechin (~115%) after SCOBY fermentation [1,2]. In this context, SCOBY emerges as a promising tool for dermocosmetic applications and the valorization of by-products. Ziemlewska et al. [102] investigated fermented extracts of *Raphanus sativus* L. leaves and roots, highlighting their use as skin-conditioning and preservative agents. Fermentation for 7, 14, and 21 days increased secondary metabolites, antioxidant activity, and protective effects against oxidative stress in fibroblasts and keratinocytes, without cytotoxicity and with anti-inflammatory effects (IL-1β and COX-2 inhibition). Application tests confirmed improved skin hydration and reduced transepidermal water loss [102]. Similarly, Stanek-Wandzel et al. [103] demonstrated that grape stem extracts fermented with SCOBY (10 and 20 days) significantly enhanced antioxidant activity and phenolic content, improving hydration and skin barrier function [103]. These strategies effectively add value to agricultural by-products and offer eco-friendly solutions for cosmetic formulations.

SCOBY for Dental Materials

The human oral cavity hosts a complex and dynamic microbiota in symbiosis with the host. However, factors such as diet, dental caries, and periodontal disease can disrupt this balance, promoting the proliferation of pathogenic microorganisms and requiring therapeutic intervention. The rising resistance to antibiotics has intensified the search for safe and effective alternative therapies [104]. In this context, SCOBY has emerged as a promising candidate when combined with bioactive materials for oral health applications [105–107]. Dental applications of SCOBY-derived bacterial cellulose are emerging through hybrid formulations with chitosan and selenium nanoparticles, which demonstrated cytocompatibility, antioxidant, anti-inflammatory, and antimicrobial properties [105,106]. Additionally, cellulose-coated orthodontic ligatures showed sustained antibacterial activity for up to 28 days while maintaining mechanical performance, suggesting promising potential for preventive dentistry [107]. Such bioengineered formulations hold considerable clinical potential, both in conventional devices and in preventive strategies for sustained release. Nevertheless, despite encouraging in vitro outcomes, further in vivo studies and clinical trials are essential to validate their efficacy and safety prior to adoption in dental practice.

3.3.4. Food Technology

Active Packaging

In this sector, seven papers address the use of SCOBY as active packaging [92,93,115–119], representing approximately 6% of the 117 studies analyzed. The highest score was achieved by El-Shall et al. [116], ranked 24th in the InOrdinatio index. It is important to highlight that all these articles were published in the last two years (2023–2024), demonstrating the growing and up-to-date interest in this material. Bacterial cellulose derived from SCOBY forms a film with high antimicrobial and antioxidant activity. However, its hydrophilic nature may limit certain applications, and modification strategies, such as blending with polymers or applying natural hydrophobic coatings, are recommended to enhance its versatility [118]. Poly (lactic acid) (PLA) stands out among biopolymers as one of the most widely used biodegradable plastics, primarily due to its environmental friendliness, commercial availability, and competitive cost in comparison to conventional polymers. As such, it has become an attractive material for enhancing the applicability of SCOBY-derived cellulose in food packaging systems [93]. Positive results were observed in terms of structural and mechanical performance, with increased strength and flexibility proportional to the incorporation of BC derived from SCOBY. The films also exhibited antioxidant properties, even when using plasticized PLA matrices [115], including those based on mechanically recycled PLA subjected to three simulated processing cycles [93]. In addition, less explored materials, such as those presented by Jiang et al. [92], involved the modification of kombucha-derived bacterial cellulose films with long-chain alkenyl succinic anhydrides (specifically 2-octenylsuccinic anhydride), resulting in antimicrobial materials with excellent resistance to water, water vapor, oxygen, and UV light. These films showed practical potential by extending the shelf life of packaged strawberries, while also being biodegradable and recyclable, thus standing out as a promising alternative for sustainable food packaging applications [92]. Similarly, El-Shall et al. [116] developed edible films based on composites of carboxymethyl cellulose (CMC), pomegranate anthocyanin extract (PAE), and bacterial cellulose derived from kombucha SCOBY. These formulations exhibited significant antioxidant activity, as demonstrated by DPPH radical scavenging assays, and showed strong antimicrobial effects against relevant foodborne pathogens, including Gram-negative (*Pseudomonas aeruginosa*, *Salmonella* sp., *Escherichia coli*), Gram-positive (*Listeria monocytogenes*, *Staphylococcus aureus*) bacteria, and the fungus *Candida albicans*. When applied as packaging for red grapes and plums, the films extended fruit shelf life by up to 25 days [116].

SCOBY in Food Technology

Among the 117 papers analyzed, eight studies (representing 9% of the total) explored novel applications of SCOBY in the development of new food products [108–114,132]. BC produced by SCOBY is structurally identical to plant cellulose but exhibits higher purity and a well-organized nanofibrillar structure [133]. Although it is not digested by the human gastrointestinal tract, it behaves as an insoluble dietary fiber, contributing to intestinal health [134]. The microorganisms present in SCOBY, widely used in kombucha fermentation, are considered safe for consumption. Although SCOBY itself, as an isolated ingredient, does not yet have formal GRAS (Generally Recognized as Safe) status, its main microbial constituents, as well as bacterial cellulose, are widely accepted for use in food applications [1]. The growing demand for natural products with functional properties makes innovation a key factor in the development of foods that meet the expectations of increasingly health-conscious consumers. In this context, several formulations have stood out for not only achieving good sensory acceptance but also promoting chemical, physical, and nutritional improvements in the final product. Examples include dairy milk beverages fermented with SCOBY [109], culinary applications [110], bakery products [111,112], and formulations such as ice creams [113] and jams [113], where the use of SCOBY contributes to physicochemical stability and adds both nutritional and functional value to foods.

SCOBY for Pickering Emulsions

Among the 117 articles analyzed, 3 papers (≈2.6%) specifically addressed the use of SCOBY in Pickering emulsions. All these studies are recent, highlighting a promising application for bacterial cellulose, which is increasingly explored in the scientific community: its use as a stabilizer in Pickering emulsions, especially in the form of nanocellulose particles, due to their superior emulsifying properties [135]. Pickering emulsions are surfactant-free, green, and sustainable systems in which solid particles, such as edible proteins, polysaccharides, lipids, waxes, and polyphenol crystals, are irreversibly adsorbed at liquid–liquid or air–liquid interfaces, as illustrated in Figure 13.

These emulsions exhibit high stability against droplet coalescence and flocculation, low toxicity, and represent a viable alternative for the valorization of industrial by-products that would otherwise be discarded; they can also serve as delivery systems [136]. One example is SCOBY, which is frequently discarded without any further application. Recent studies highlight the potential of BC derived from kombucha as a stabilizer in Pickering emulsions, with distinct yet complementary approaches. Cellulose nanofibrils obtained through high-pressure homogenization were used to stabilize emulsions containing curcumin dissolved in olive oil, resulting in systems with high thermal and UV stability and notable antioxidant activity [121]. In another study, BC nanocrystals obtained via acid hydrolysis were used to stabilize camellia oil emulsions incorporated into alginate–anthocyanin films. These films exhibited enhanced barrier, mechanical, and antioxidant properties, in addition to pH-sensitive color changes, making them effective freshness indicators for products like yogurt [137]. Together, these studies demonstrate the versatility of KBC as a functional material in sustainable formulations, either as a bioactive delivery system or as an active component in intelligent food packaging. Their use enables the development of clean-label, functional, and environmentally friendly products. As a result, Pickering systems align with current industrial demands for safer, more stable, and sustainable formulations.

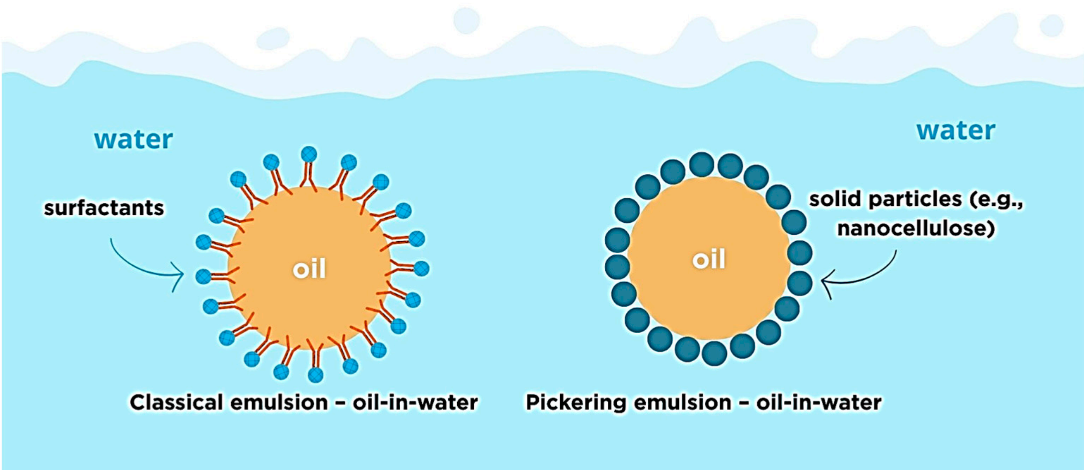

Figure 13. Schematic representation of a Pickering emulsion mechanism. Adapted from Xia, Xue, and Wei [136].

4. Conclusions

This systematic review, guided by the *Methodi Ordinatio* approach, allowed the identification and classification of the most relevant scientific studies on the use of SCOBY derived from kombucha fermentation. Currently, the global kombucha market remains strongly driven by beverage consumption, which creates an optimistic scenario for the valorization and expansion of SCOBY as a valuable by-product. The analysis of 117 selected articles highlighted a significant growth in publications over the past five years. China, India, the United Kingdom, the United States of America, and Brazil were the principal contributing countries in this field. The four key sectors in which SCOBY demonstrates considerable potential include bacterial cellulose production, sustainable materials, biomedical innovations, and food-related applications. Among these, the production and modification of bacterial cellulose stood out, especially through the development of nanocellulose and the exploration of alternative cultivation strategies aimed at enhancing yield, reducing costs, and aligning with circular economy principles. As a sustainable material, SCOBY has been applied in water treatment, the textile sector, electrochemical devices, and eco-friendly composites. In the biomedical field, it exhibits functional properties that make it suitable for wound healing, tissue engineering, dermocosmetics, and dental applications, primarily due to its cytocompatibility and antibacterial activity. In the food sector, SCOBY-derived cellulose has been explored as a material for active packaging, novel culinary applications, and as a precursor for emulsion systems. The findings reinforce the value of SCOBY not merely as a fermentation by-product, but as a versatile and promising raw material capable of addressing urgent demands for eco-friendly and functional materials. Future development efforts should focus on the functionalization and chemical modification of SCOBY-derived materials, while also addressing key aspects such as safety, biocompatibility, standardization, regulatory approval, and industrial certification. These advances are essential to support the broader integration of SCOBY-based products into commercial applications. Notably, these emerging applications lie within high value-added and high-demand sectors, further underscoring the economic, technological, and environmental potential of SCOBY as a sustainable raw material capable of addressing urgent global demands for eco-friendly and functional biomaterials.

Although this review provides a comprehensive mapping of the literature on kombucha-derived SCOBY, several limitations related to the included studies should be acknowledged. First, many of the selected articles did not report standardized methodologies for SCOBY production or characterization, which hinders direct comparison across studies. Second, a significant number of studies were conducted at the laboratory scale, with limited industrial applicability or scalability data. Third, variability in microbial strains, substrates, and culture conditions among studies introduces heterogeneity that may affect the generalizability of the findings. Additionally, the lack of long-term evaluations or in vivo data in several biomedical and packaging applications constrains the extrapolation of results to real-world conditions. These limitations should be considered when interpreting the evidence and highlight the need for more standardized, scalable, and application-driven research in this field.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fermentation11100589/s1, Section S1: The total description of the *Methodi Ordinatio* phases applied to the use of SCOBY derived from kombucha fermentation; Section S2: PRISMA 2020 Checklist with flow diagram; Section S3: Table with the full classification of the 117 articles, with the *Methodi Ordinatio*. References [138–142] are cited in the Supplementary Materials.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AgNPs	Silver Nanoparticles
Au-CBC	Gold Nanoparticle-Functionalized Chitosan-Bacterial Cellulose Composites
BC	Bacterial Cellulose
BNC	Bacterial Nanocellulose
BOD	Biological Oxygen Demand
CBC-Au	Gold Nanoparticles in Chitosan-Bacterial Cellulose Composite
CMC	Carboxymethyl Cellulose
COD	Chemical Oxygen Demand
EDS	Energy Dispersive X-ray Spectroscopy
FeNPs	Iron Nanoparticles
FTIR	Fourier Transform Infrared Spectroscopy
GRAS	Generally Recognized As Safe
HAp/TiO_2	Hydroxyapatite/Titanium Dioxide Nanocomposites
HC	Hydrolyzed Collagen
HGBC	Hydrogel Bacterial Cellulose
IRR	Internal Rate of Return
JCR	Journal Citation Reports
KBC	Kombucha-Derived Bacterial Cellulose
LFMs	Living Filtration Membranes
PAE	Pomegranate Anthocyanin Extract
PLA	Polylactic Acid
PMMA	Polymethyl Methacrylate
ROI	Return on Investment
SCOBY	Symbiotic Consortium of Bacteria and Yeast
SeBNCSFa	Selenium Nanoparticles Ferulic Acid-Grafted Chitosan
SeNPsK	Selenium Nanoparticles Biosynthesized via Kombucha Fermentation
SeNPsSb	Phyto-Synthesized Selenium Nanoparticles
SNHA	Nanocellulose-Based Composite Coated with Hydroxyapatite
VFD	Vortex Fluidic Device
ZnO NPs	Zinc Oxide Nanoparticles

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