SUGAR ALCOHOLS: WHAT HAS BEEN LEARNED SO FAR? - A BIBLIOMETRIC REVIEW

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ABSTRACT

Sugar alcohols, like xylitol, arabitol, sorbitol, mannitol, and erythritol, are versatile compounds widely used in various industries due to their unique properties. Sustainably obtained from biomass, these polyols have a wide range of applications, from the food industry to phase change materials production. This review examines the evolution of studies on sugar alcohols and highlights the main scientific themes associated with these molecules. From the earliest citations to the present day, sugar alcohols have been studied for their relevance in replacing sugar, with an emphasis on functional benefits and sustainability. The biotechnological production of these compounds has gained prominence due to its lower environmental impact. Additionally, new research areas such as energy fuels have emerged, exploring sugar alcohols as materials for thermal energy storage. Therefore, it was possible to obtain a comprehensive and up-to-date view of the growing scientific interest in sugar alcohols and their potential applications.

Keywords: Biomass products. Biotechnological processes. Food ingredients. Polialcohols. Systematic review.

1 INTRODUCTION

Sugar alcohols, also known as polyols, represent a class of compounds widely used in various industries due to their unique and versatile properties. These compounds, which include xylitol, arabitol, sorbitol, mannitol, erythritol, among others, are characterized by having a chemical structure similar to sugars, but are typically produced by the reduction of originally carbonyl groups to alcohols. Their sustainable production from lignocellulosic biomass and wide range of properties and applications, ranging from the food industry to the production of phase change materials, make sugar alcohols objects of increasing interest in scientific research and the development of new products and technologies. In this context, this review seeks to explore bibliometrically the temporal evolution of studies on sugar alcohols and to expose the main scientific thematic groups associated with these molecules[1,2].

2 MATERIAL & METHODS

Initially, data collection was conducted based on scientific publications cataloged in the Web of Science Core Collection (WoS). Next, the search was performed in the "advanced search" section using the search term "Sugar alcohol*", indicating the possibility of including "sugar alcohol" or "sugar alcohols". This term was entered in the "topic" field of Web of Science, which searches for titles, abstracts, author keywords and keywords plus®. The search was conducted without date restrictions, covering all articles published up to the year 2023. This approach allowed tracking the evolution of research over the years. The selection was limited to articles and review studies, with no language restriction. Finally, the dataset obtained was exported and analyzed using the bibliometric software VOSviewer, responsible for processing textual data and generating bibliometric graphs.

3 RESULTS & DISCUSSION

From the search conducted, 3076 articles published up to 2023 were found, including 2840 research articles and 236 review articles. The earliest works to publish the term "sugar alcohols" date back to the 1920s and 1930s. These initial works are primarily associated with chemical reactions involving sugar alcohols for compound production, identification of their occurrence in nature, and initial characterizations[3,4]. Over time, there has been an increase in the average number of articles per year, starting from 1.5 articles per year from 1925 to 1969 and reaching 212.8 from 2020 to 2023 (Figure 1), highlighting a growing interest in the topic over time.

From the earliest citations until the 1960s, the main themes associated with sugar alcohols publications were related to chemistry, medicine, microbiology, and plant sciences. In 1935 was published the first work associating sugar alcohols with a sweet taste[3]. It became evident the need for the initial characterization of the compounds, understanding their role in organisms and highlighting potential applications. From 1970 onwards, Food Science and Technology emerged as the main theme, with the use of polyols as sugar substitutes[5]. In this context, aspects related to Dentistry and Nutrition also became relevant, evaluating the beneficial effects of substituting sugar with sugar alcohols for oral health and in the human body[6,7].

From 1990 to 2009, biotechnology became the main theme, with the study of biotechnological production of sugar alcohols replacing chemical methods, such as the conversion of D-xylose into xylitol and glucose and fructose into mannitol by yeasts and bacteria[8,9]. From 2010 to 2023, Food Science and Technology returned to the position of main theme, highlighting more consolidated role of sugar alcohols as sugar substitutes that offer functional benefits. However, it is worth noting that a new area has emerged and expanded over the last 10 years: energy fuels, which now occupies the sixth position in thematic relevance, exploring sugar alcohols as phase change materials for thermal energy storage[10].

In general, the main themes developed on the topic of sugar alcohols were associated with chemistry, biotechnology, food, and plant sciences. Over time, interest in the subject has increased, shifting from content associated with identification and characterization to production and various possible applications of the compounds. As a consequence, there has been a greater distribution of the proportion of articles by theme in more recent periods, revealing the development of different associated research lines, including the emergence of new relevant thematic areas.

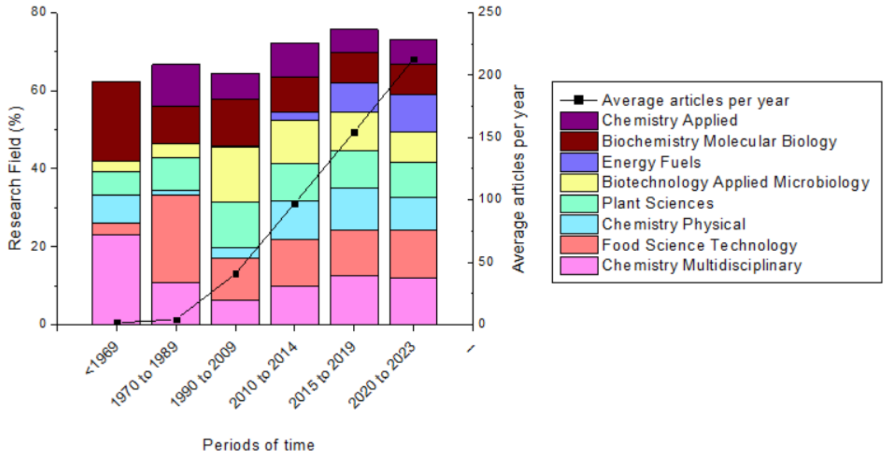

Figure 1 Average number of articles related to "sugar alcohols" and distribution by research field by time period.

The bibliometric author keywords map presented in Figure 2 was generated from the bibliometric data analyzed by the VOSviewer software, with a filter of at least 12 occurrences per keyword. Fifty-nine keywords grouped into thematic clusters were displayed, classified as follows: chemical production (navy blue), biotechnological production (purple), dental caries (cyan blue), sweeteners (brown), physical properties and applications in materials (green and yellow), plant metabolism (red), and biomass burning (orange).

Chemical production is associated with synthesis processes from carbohydrates as raw materials, such as xylose and glucose, which are renewable materials. These compounds undergo catalytic hydrogenation processes to convert sugars into polyols. The advantage of this method lies in its ability to produce large quantities of these polyols with high purity and in a short time frame, making it still a viable option to meet industrial demand for these compounds in various sectors, including food, pharmaceuticals, and cosmetics. However, this process may be less sustainable compared to biotechnological production, as it may require the use of metallic catalysts and high energy demand[2,11].

Biotechnological production of sugar alcohols has increased interest due to its lower environmental impact, as it requires less energy and does not necessitate metallic catalysts. These processes typically involve the use of microorganisms, such as fungi and bacteria, capable of converting carbonaceous substrates into sugar alcohols through fermentation. However, the yield and efficiency of biotechnological processes remain an obstacle, leading to the search for new microorganisms, fermentation strategies, and genetic engineering methods to optimize the production of these compounds. Biotechnological production offers a more sustainable and economical alternative for obtaining these polyols, promoting the more efficient utilization of biological resources[2,12].

Whether through chemical or biotechnological means, sugar alcohols produced can be widely used in the food industry. These molecules have been the subject of study in food technology due to their sweetening potential in foods and beverages intended for consumers seeking to reduce calorie intake or control blood glucose levels, such as those with diabetes. In addition to providing a sweetness similar to sucrose, sugar alcohols have the advantage of not contributing to the formation of dental caries, making them ideal for oral health products such as chewing gums. Furthermore, these compounds possess unique properties, such as moisture retention and mouth-refreshing effects, making them desirable ingredients in a variety of food products, including chocolates, ice creams, candies, confectionery, and bakery products. However, excessive doses of sugar alcohols can cause gastrointestinal side effects, such as gas and diarrhea, and therefore, it is important to consume them in moderation[13,14].

In addition to food applications, the recent association between sugar alcohols and energy fuels lies in the fact that sugar alcohols have properties for storing and releasing large amounts of thermal energy during phase change at specific temperatures. These compounds can be incorporated into different construction materials, textiles, or refrigeration systems to harness their potential for thermal energy storage. Furthermore, such energy storage capacity enables application in eco-friendly energy technologies[10].

Regarding the association between sugar alcohols and biomass burning, this concerns the fact that during the combustion of plant biomass, sugar alcohols can be released into the atmosphere as byproducts of thermal decomposition of sugars. These compounds are released into the atmosphere and its presence in the atmosphere can have environmental impacts, negatively contributing to formation of organic compounds and air quality. Additionally, analyzing the presence of these compounds in atmospheric samples can provide useful information about biomass burning patterns and their associated emissions, aiding in studies on climate change and atmospheric quality[15].

Finally, one aspect that has historically been studied is the role of sugar alcohols in plant metabolism. This occurs because some polyols are produced as secondary metabolites and play regulatory roles in plant growth and defense against biotic and abiotic stresses, enhancing resistance to stress conditions such as drought, salinity, and extreme temperatures[16].

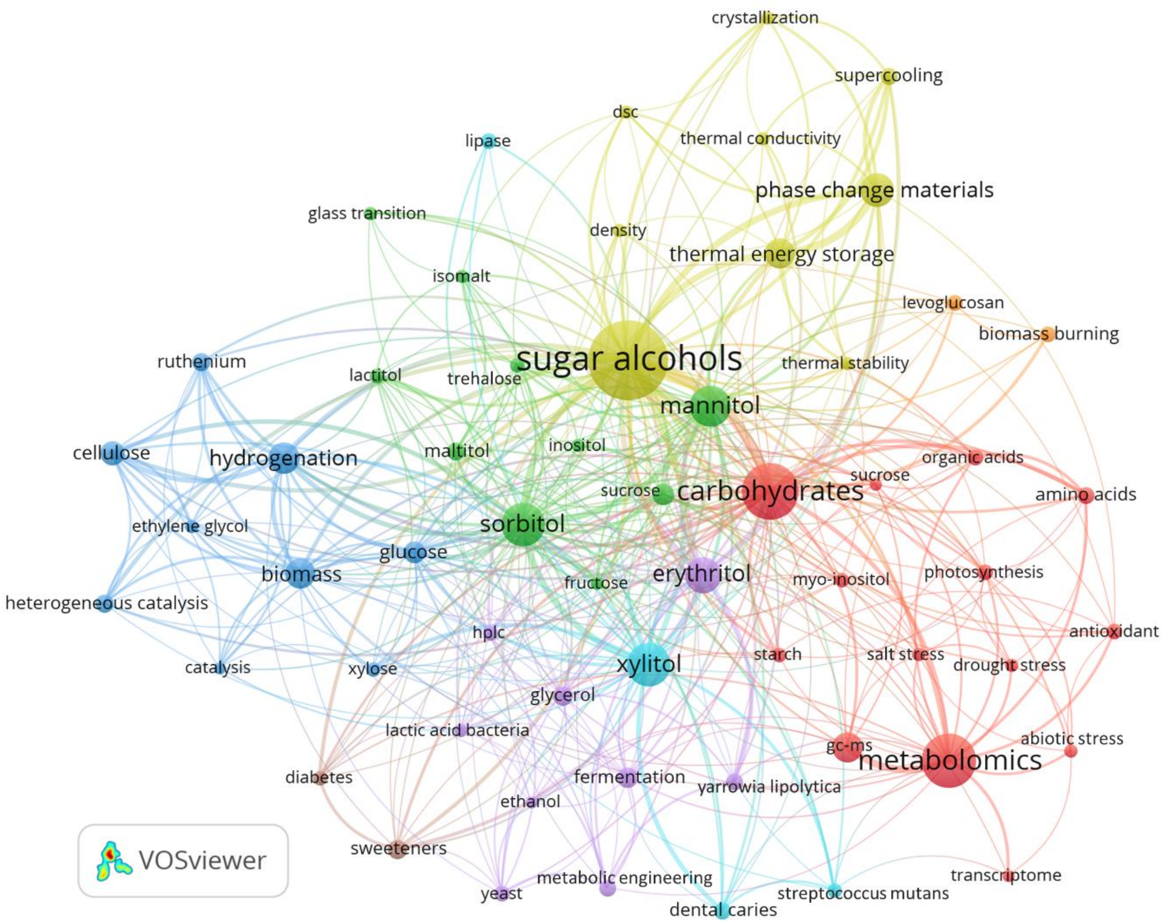

Figure 2 Network map with most occurring keywords and co-ocurrence clustering by colors.

4 CONCLUSION

Through the bibliometric and thematic review conducted, it was noted that sugar alcohols represent a group of molecules that are attracting increasing scientific interest. It was evident that biotechnological production strategies constitute a sustainable alternative to chemical pathways. Furthermore, regardless of the production method, there are traditional and emerging fields of application for such molecules, which, being obtained from plant biomass, constitute a relevant chemical group in the context of sustainable resource utilization, circular economy, biorefinery, and sustainable development.

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