EVALUATION OF BRAZILIAN CONTRIBUITON TO SUSTAINABLE DEVELOPMENT THROUGH MICROWAVE-ASSISTED ORGANIC SYNTHESIS

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Abstract:

Chemistry's commitment to Sustainable Development (DS) can be called Green Chemistry (GC), which aims to create and implement chemical practices that are less harmful to the environment, avoiding or reducing the negative impact of chemical products or processes. This work aims to assess the Brazilian contributions to sustainable development and the Sustainable Development Goals (SDGs) through a systematic review of publications focused on microwave-assisted organic synthesis. It was possible to observe that all selected works contributed to ODS 7, reducing reaction time and increasing energy efficiency. So, in addition to the use of microwave radiation, other Green Chemistry (GC) strategies were also used, such as the use of catalysts, the use of green solvents, and concern in waste generation.

Keywords: Sustainable Development Goals; Green Chemistry; Microwave assisted organic synthesis.

AVALIAÇÃO DA CONTRIBUIÇÃO BRASILEIRA PARA O DESENVOLVIMENTO SUSTENTÁVEL ATRAVÉS DA SÍNTESE ORGÂNICA ASSISTIDA POR MICROONDAS

Resumo:

O compromisso da Química com o Desenvolvimento Sustentável (DS) pode ser expresso através da Química Verde (GC), que visa criar e implementar práticas químicas menos nocivas ao meio ambiente, evitando ou reduzindo o impacto negativo de produtos ou processos químicos. Este trabalho visou avaliar as contribuições brasileiras para o desenvolvimento sustentável e os Objetivos de Desenvolvimento Sustentável (ODS) por meio de uma revisão sistemática de publicações com enfase em sintese orgânica assistida por micro-ondas. Foi possível observar que todos os trabalhos selecionados contribuíram para o ODS 7, diminuindo o tempo de reação e aumentando a eficiência energética. Pode-se concluir que, além do uso de radiação micro-ondas, também foram utilizadas outras estratégias da Química Verde (GC), como o uso de catalisadores, uso de solventes verdes e uma preocupação na geração de resíduos.

Palavras-chave: Objetivos de Desenvolvimento Sustentável; Química Verde; Síntese Orgânica Assistida Por Micro-ondas.

1. INTRODUCTION

In 2015 the United Nations (UN) created the 2030 Agenda with the purpose of promoting Sustainable Development (SD), This project aims to end poverty and hunger, protect the planet through sustainable consumption and production together with the management of natural resources, and strengthen peace and prosperity, based on the triple bottom line. To this end, 17 Sustainable Development Goals (SDGs) and 169 individuals targets were proposed [1]. To meet the SDGs on a large scale chemistry must be applied following the guidelines of Green Chemistry (GC) [2], being able to cover almost all 17 SDGs, either directly or through the targets stipulated in each SDGs [3].

The GC movement emerged in the 1990s in the United States of America involving academia and industry through the creation and implementation of chemical practices that are less harmful to the environment [4], avoiding or minimizing the negative impact of products and Chemical processes, caused to humans and the environment, through increased process safety, decreased emission of toxic substances and increased energy efficiency [5]. The green or sustainable concept is essential to achieve social, environmental and economic goals [5], and through its growth it promotes innovations that contribute to environmental benefits, with economic gain and social well-being [6].

Synthesis is the discipline of chemistry in charge of creating molecules such as drugs, polymers, new materials, in order to contribute to social and economic well-being and progress [7]. Atomic economy, use of catalysts and solvent-free conditions are GC principles linked to synthesis. The use of biocatalysts, use of clean energy sources, renewable reagents are prominent themes in this field [3].

Organic synthesis is highlighted due to its importance for the pharmaceutical industry, which often presents high formation of waste [8]. The concern with a possible scarcity of non-renewable resources combined with the principles of GC lead researchers to look for renewable sources of raw material. In order to achieve these goals Landim et al., 2019 [9] reported the synthesis of copolymers of urea and succinic acid, and urea, succinic acid and glycerol, through a mechanochemical polymerization, without the use of solvents or catalysts. In addition to their importance for the agroindustry, the synthesized polymers can be interesting for the pharmaceutical, food and cosmetic industries and demonstrate the possibility of more ecological polymerizations through mechanochemical reactions.

Microwave-assisted organic synthesis has grown in recent years. The use of microwaves in organic synthesis presents significant improvements when compared to conventional heating, as it presents selective heating, reduction in reaction time, greater conversion, and the possibility of not using solvents [10].

In this context, the present work aims to carry out a systemic review in green chemistry and microwave-assisted organic synthesis in Brazil, and to evaluate the contributions in this area of research to sustainable development and its SDGs.

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2. METHODOLOGY

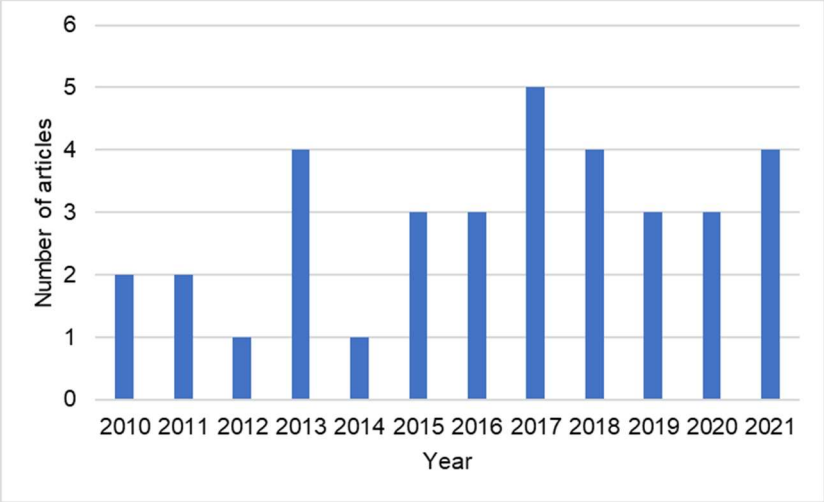
The present study was consisted of searching for articles with the words “green chemistry” and “Microwave assisted organic synthesis” in Portuguese and English. A research was carried out in the Scielo and Web of Science (WOS) indexes, articles published by Brazilian institutions between the years 2010 and June 2021. The selected articles were those that demonstrated in the title, abstract or conclusion the benefit (s) found with the study tied to guidelines of GC. After selection, the articles were evaluated to obtain data related to the SDGs that were achieved from the study.

3. RESULTS AND DISCUSSION

The research was made in Scielo and Web of Science with the words "Green Chemistry" and "Microwave assisted organic synthesis" for the years 2010 and 2021. In total, 50 works were found and were selected for further reading those works that presented in their abstract, introduction and/or conclusion the benefits linked to GC and the use of microwaves and were available in full on the platforms. Thus, after removing the duplicated works, 35 were selected for reading to obtain data referring to the institutions where the work was carried out and the SDGs that were benefited.

It was found that most articles published on microwave-assisted organic synthesis were concentrated between the years 2015 and 2021 (Figure 1).

Figure 1. Number of articles published per year on microwave-assisted organic synthesis for the period 2010-June 2021.



The Figure 2 shows that in the evaluated period the largest number of scientific articles related to microwave-assisted organic synthesis resulted from studies carried out by researchers linked to institutions located in 11 Brazilian states, especially in Rio Grande do Sul, São Paulo, Santa Catarina and Minas Gerais.

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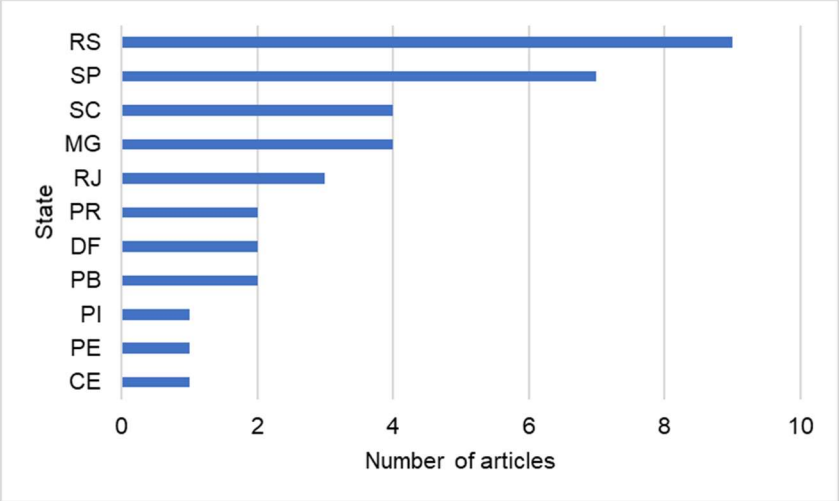
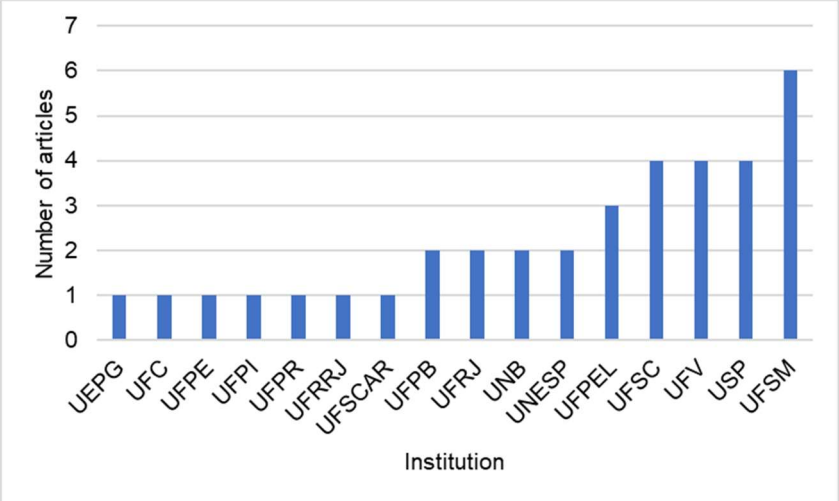
Figure 2. Number of articles evaluated focusing on microwave-assisted synthesis by state.



There was a great contribution from researchers at the Federal University of Santa Maria (UFSM) with 6 studies and from the Universities of São Paulo (USP), Federal University of Santa Catarina (UFSC) and University of Viçosa (UFV) with 4 studies each, as can be noted in Figure 3.

Figure 3. Number of articles studied by institution, related to microwave-assisted synthesis. Period 2010-2021



The number of articles by institutions and by states (36) is higher than the total number of studies analyzed (35), because for the study developed by Azeredo et al., 2014 [11] two corresponding authors from different institutions were indicated, UFSC and UFSM, based in the states of Santa Catarina and Rio Grande do Sul.

From the analysis of the articles, it was possible to verify that the researches contribute with 6 SDGs, listed below: SDG 3, SDG 6, SDG 7, SDG 9, SDG 12 and SDG 14 (Figure 4).

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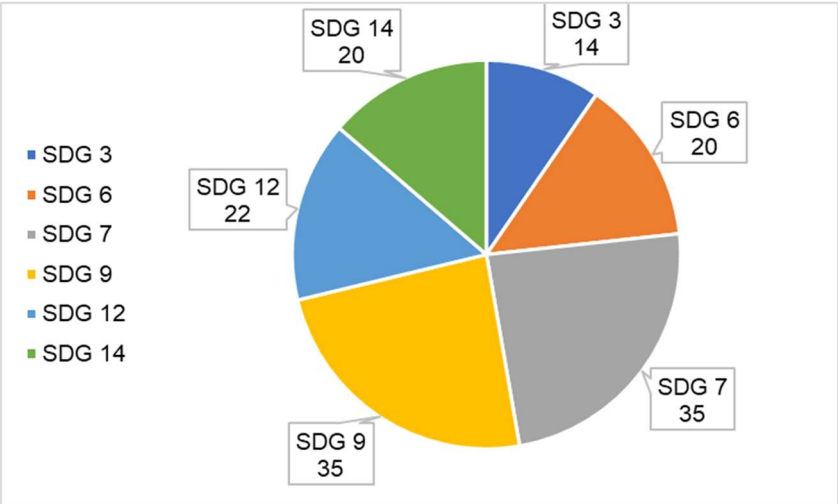
Figure 4. Number of articles related to the SDG's



All 35 studies analyzed contributed to SDG 7, through target 7.3 which aims to increase energy efficiency. Thus, with the use of microwave radiation, the work developed reduced the time needed to carry out the reaction and, consequently, obtained the desired compounds with less energy expenditure. In addition, the studies also contributed to the SDG 9 through target 9.5, as they take innovation to scientific research with the use of microwave irradiation, replacing in a sustainable way the synthesis methods that use conventional heating.

It was observed that the studies developed in 20 articles met SDG 6 and SDG 14 through goals 6.3 and 14.1 (Annex 1). In addition to the use of microwave radiation, these studies proposed improvements over the use of green solvents or solvent-free reactions. It was also noted the concern in the use of transition metals and non-toxic catalysts.

In 22 articles, it was found that the proposed methods contribute to SDG 12 through goals 12.4 and 12.5. These goals aim to reduce the disposal of chemical waste into the environment through reduction, recycling and reuse. It is noteworthy that these studies proposed procedures that enabled the reuse of catalysts, the use of reused and renewable reagents, and the concern with the waste generated throughout the process.

The contribution of 14 works to SDG 3 can also be seen through goals 3.b and 3.8. The studies developed proposed the synthesis of compounds that may be candidates to become medicines or carried out tests to verify the efficacy of the synthesized substance as a medicine drugs.

Figure 5 shows the 5 authors with the most publications on microwave-assisted organic synthesis in Brazil, which are: Sérgio Fernandes (UFV), Antônio Braga (UFSC), Marcos Martins (UFSM), Claudio Silveira (UFSM) and Carlos Andrade (UNB) with 4, 3, 2, 2 and 2 articles, respectively.

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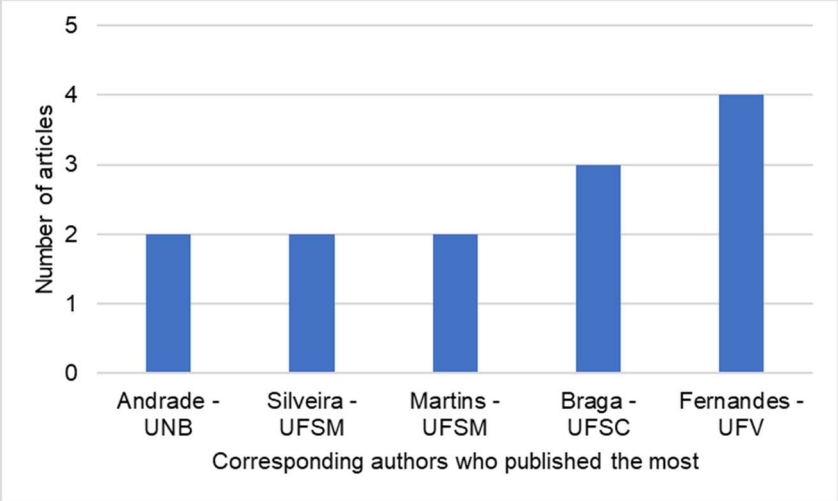
Figure 5. Number of articles per corresponding author, related to microwave assisted synthesis. Period 2010-2021



Among the works analyzed, the study published by Lenardão et al., 2011[12] report the synthesis of vinyl sulfide using glycerol as a recyclable solvent was reported, which complies with principle 7 of GC. It has also been reported to reuse catalyst up to 5 times without losing catalytic efficiency. Also following this line of catalyst reuse, De Paiva et al., 2019 [13] performed the microwave-assisted synthesis of juliodines and obtained 92% yield in just 10 minutes of reaction.

Pissurno and De Laurentiz, 2017 [14] reported the synthesis of 4-azo-butenolides through microwave heating. The proposed methodology presented a high yield (98%) with acetonitrile as solvent and presented a shorter reaction time (30 – 40min) than those obtained from the methods found in the literature (48 – 144h).

Seeking to perform syntheses more efficiently, Vargas et al., 2012 [15] reported obtaining 1-aryl-4-dimethylamino methyleno-pyrrolidine-2,3,5-triones, an important heterocyclic building block, using microwave radiation, using ethanol as a solvent and with a reaction time between 12 to 16 minutes, whereas in the traditional heating synthesis it takes 8 to 16 hours.

Given the importance of developing new drugs, Luczywo et al., 2021 [16] reported the synthesis of 2-styrylquinoline- 4-carboxylic acids that can be used in the treatment of leishmaniasis. The study showed good yield and short time to carry out the synthesis, it also found that this substance is not toxic to the host cell.

De Andrade et al., 2015 [17] reported the microwave-assisted synthesis, in 10 minutes of triazole bases analogous to benznidazole, a drug for the treatment of Chagas. Two compounds synthesized by the authors showed similar activity, and one was shown to be more active in combating the protozoan.

Bonacorso et al., 2016 [18] reported a new methodology for the synthesis of methyl 3-ferrocenyl-1H-pyrrole-2-carboxylates using microwave heating. Through the traditional method, this synthesis required a long time to be completed (18h) and has a low yield of 40%, while through the proposed method it took 30 min and 70% yield was obtained.

Finally, Da Rosa et al., 2020 [19] demonstrated the synthesis of thiocarbamoylpyrazoles with the intention of being used as a powder for fingerprint

detection, using microwaves. As advantages, shorter times to complete the reaction were observed, ranging from 5 to 15 minutes, it does not generate residue in the purification column and the yields are similar to the classic reaction, which takes 4 hours to be completed.

4. CONCLUSION

This review assessed the Brazilian contribution to sustainable development through publications on microwave-assisted organic synthesis. It was possible to observe that all articles contributed to the SDG 7, as they considerably reduced the synthesis time, consuming less energy for heating. It was also possible to observe the authors' concern with other GC principles such as atomic economy, the use of safer catalysts, solvents and auxiliary reagents and the use of renewable raw materials. Thus, most works were able to contribute to SDGs 6, 12 and 14, as they proposed improvements related to the use of green solvents or solvent-free reactions, used renewable reagents and/or reused catalysts. It is remarkable the advance of research related to the synthesis of new drugs that contribute to GC and DS, generating less waste and presenting greater energy efficiency, in order to contribute to the development of safer drugs and, consequently, contribute to SDG 3.

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6. OTHER INFORMATION

If you have any questions about the SDGs and their goals, check the website: https://sdgs.un.org/goals.

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