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Critical analysis of research trends and issues in microwave assisted extraction of phenolics: Have we really done enough

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ABSTRACT

In the last five years microwave assisted extraction (MAE) has gained tremendous research interest as evident from the number of publications recorded in Scopus. This particular review article on MAE of phenolics/flavonois/antioxidant principles from plants addresses different operational and conceptual issues which govern the entire process and presents a critical analysis of the same. The manuscript has been divided into pre-extraction and post-extraction issues, questions have been raised and suitable resolutions have been opined. This review which describes the basic research trends in MAE of phenolics from plants shall be a basic stepwise guideline for any industries planning to adopt this technology at a large scale. This article shall highlight the pros and cones of this technology so that the industries can perform a cost-benefit analysis of each step which shall dictate the feasibility of the project.

Contents

1. Introduction

Phenolic compounds are a group of aromatic secondary plant metabolites widely spread throughout the plant kingdom with proven track record in reducing the risk of onset of many chronic diseases such as cancer, cardiovascular and neurodegenerative problems and also has a positive intervention in the pathological pathway for the effective management of such chronic diseases [1–4]. Scopus search revealed that in the past ten years (2005–2015) 49,230 articles have been published which had the word phenolics either in their abstract, title or keywords [4,5]. This clearly shows the intensity of research going on related to phenolics. Industries definitely would be interested to explore any scientific research interventions in phenolics and in this regard nothing could be as attractive as exploring large scale economic extraction of phenolics. Recently a great deal of work has been published in developing newer extraction methods for the extraction of bioactives from plants [6]. Among the newer techniques microwave assisted extraction (MAE) and ultrasound assisted extraction (UAE) have gained considerable focus and attention due to their low instrument set-up cost at laboratory scale. Nevertheless, supercritical fluid extraction and accelerated/pressurized solvent extraction are also in use but may be due to their high basic instrumental set-up cost has not been

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among the focus of attraction at-least when evaluated in terms of number of publications recorded in Scopus. Scopus search revealed 29 review articles associated with MAE of phenolics/flavonoids/antioxidant principles from 2005–2015. All these articles had the word "microwave assisted extraction" and "phenolics" or "flavonoids or "antioxidant" either in the title or abstract or keywords. All these articles had their focus primarily on the working mechanism of MAE, chemistry of phenolics, factors influencing extraction conditions, post extraction clean up and chromatographic conditions for quantification [7–11]. Now with so much of literature already existing in the scientific domain it becomes a very challenging issue to write a fresh review article. Nevertheless, close analysis of such review articles which are extremely valuable literatures revealed that these articles are meant for those who already have prior knowledge on MAE operations. A beginner or an industry intending to make a set-up of MAE unit will find it difficult to cope up with these articles as they demand prior understanding of the subject knowledge as a prerequisite for reading those articles. These articles are basically literature reviews comprising of collection of optimization data on MAE of phenolics reported by different researchers in different span of time. Different optimized conditions reported for different plants make it more complicated to frame a generalization on the optimum conditions of MAE of phenolics. In other words it raises an issue that whether each single plant needs separate optimum conditions for MAE or enough research has been done which is sufficient to make a generalization on the conditions required for optimum extraction. Henceforth, a need of a review article was felt which could present a critical analysis of research trends in MAE of phenolics and highlight all major issues pertaining to this area of research in a step wise pattern. This review article is written with the intention to make its readers (first timers in the field of MAE of phenolics/botanicals) to understand the core concept behind the operations involved and also makes an attempt to address major issues which one needs to resolve before making a venture with MAE of phenolics. This review article also raises questions on the novelty aspect of such work. The article is basically a statutory guideline for an industry which is planning to adopt such technologies. The structure of the review articles has been divided into three parts. The first part deals with the pre-extraction issues. Second part deals with the post-extraction issues and the heart of the article is the last part which briefly highlights the key issues and value additions applicable for MAE of plant phenolics/flavonoids and antioxidant principles. A recent article by us discusses the publication trends of MAE of botanicals from 2005–2015 [6]. It indicates that a good quantity of research has been done as evident from more than 1100 research articles on MAE of botanicals recorded in Scopus from 2005–2015. Now it's high time that we make a generalization out of all these researches so that a common understanding is framed for adopting these technologies by the industries or else such technologies will find its existence only at the laboratory bench top. This review article is an attempt in that direction.

2. Data mining (2005–2015) from Scopus, critical analysis and comparison with other similar platforms

Scopus is the largest database available for multidisciplinary scientific literatures. Scopus covers more than 50 million records (more than PubMed) including trade publications, open-access journals, and book series. Almost 80% of these records include abstract. It contains more than 20,000 peer-reviewed journals from nearly 5,000 publishers, together with 1200 Open Access journals [12]. Chadegani et al. in one of their publication in 2013 reported that most of the institutions in all over the world such as Latin America, Europe, North America, Australia, Asia and the Middle East believe that Scopus have positive influence on their researches [12]. Boyle and Sherman (2006) reported that choosing Scopus is due to its quality of outcomes, time saving, ease of use and possible effect on research findings [13]. Falagas et al. in their study stated that for citation analysis, Scopus offers about 20% more coverage than Web of Science, whereas Google Scholar offers results of inconsistent accuracy [14]. Scopus being a powerful database provides different searching and browsing options. There are different searchable fields and several document types that permit the user to easily narrow their searching. The results can even be refined to quickly limit or exclude results by author, source, year, subject area, document type, institutions, countries, funding agencies and languages. Results may be printed, e-mailed, or exported to a citation manager. The results may also be reorganized according to the needs of the researcher by simply clicking on the headings of each column. A further user option is the ability to browse individual journals by simply clicking the Journals tab, locate the journal name and select the individual issue. Scopus also allows analyzing the results graphically by drawing histograms or charts. All these features can be personally experienced and also have been beautifully documented in a study reported by Chadegani et al. [12]. Looking into the numerous advantages and ease of operation coupled with accuracy in data mining through application of user friendly filters, the critical analysis presented in this subsection is based heavily on Scopus data mining. Critical analysis of Scopus data revealed that 452 articles were published which had the word "microwave assisted extraction" and "phenolics" or "flavonoids" or "antioxidant" either in their title, abstract or keywords. From these 452 articles, 74.7% articles were published during 2011–2015 which clearly indicated a late rise in research interest on developing newer extraction methods for phenolics (Fig. 1). In a recently published article through analysis of Scopus data (2005–2015) we reported that 1157 articles were published based on MAE dedicated to botanicals [6]. From 2011–2015 out of the total number of articles published on MAE of botanicals 44.47% were dedicated to phenolics/flavonoids and antioxidant principles which indicates that the bulk of the research on MAE of phenolics have been done during this period. The different search parameters used for data mining from Scopus is presented in Table 1. Using similar search parameters data mining was carried out using Google scholar and PubMed. Results were in synergism with that generated from Scopus. Google scholar reflected 10,100 articles related to the above theme out of which 74% of the articles were published during 2011–2015 indicating a sharp rise of research interest in MAE of plant phenolics during this period. PubMed search on the other hand indicated only 262 articles from 2005 to 2015 related to MAE of plant phenolics/flavonoids and antioxidant principles. Leaves were found to be the most explored plant part for extraction of phenolics. A comparative evaluation of different plant parts used for MAE of phenolics has been shown in Fig. 2. Among the different plant parts used for extraction of phenolics, leaves and fruits which are the most commonly used edible plant parts together constitutes 63.3% of the total share. Henceforth, in this regard a generalization can be made that leaves/fruits can be used as popular source for extraction of phenolics. Overexploitation won't be an issue in this case as leaves can be easily

Table 1
Parameters used in data mining from Scopus

Search parameters	Operational settings
Search term text	<microwave assisted extraction> and <phenolics> or <flavonoids> or <antioxidants>
Search field type	Article title, abstract, keywords
Data range	2005–2015
Document type	<article>
Subject areas	Life sciences, health sciences and physical sciences
Operator used between two search terms	<and>, <or> depending upon the search requirement