

ULTRASONIC ASSISTED EXTRACTION AS A POTENTIAL GREEN APPROACH FOR TRACE METAL DETERMINATION

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Abstract

An ultrasonic assisted extraction as a green way approach is described for simple, efficient and rapid determination of trace metals in some complex matrices by atomic absorption spectrometry and/or other techniques. Their optimized conditions are certainly investigated in details, in particular several variables that could affect the performance of the method in comparison with those of standard methods. In this review, arsenic species are focused to determine in chilli as the plant matrix, for example. This will lead to improve mild extraction method as a routine work for heavy metals in such food analysis with its emerging applications and future trends

1. INTRODUCTION

Fruits and vegetables, which are commonly the so-called complex matrices, are immensely valuable not only for their nutritional value but also for their efficient health functionality against various degenerative diseases caused by free radicals[1-4]. They are also good source of natural antioxidants containing many bioactive components which play a significant role in prevention of free radical formation by scavenging or promotion of their decomposition[5-9]. In particular, chilli pepper

(*Capsicum annuum* L.) is known the most cultivated species from an economic and nutritional viewpoint worldwide [10-14]. Chillies are one of the widely consumed vegetables because of the combination of color, flavor, taste and nutritional value. Apart from rich source of vitamin C, it has vitamin A and E, small quantity of proteins, fats, carbohydrates and traces of minerals. It is valued for its pungency which is due to crystalline, acrid volatile alkaloid capsaicin[15-19], having diverse prophylactic and therapeutic uses in allopathic and ayurvedic medicine. These properties are also accorded due to the presence of phenolic compounds, carotenoids and capsaicinoids [2,3]. However, trace metal contamination could affect on human and plant [20-24] because some trace metals at low doses are essential for plants, but in higher doses they may cause metabolic disorders and growth inhibition for most of the plants species. The trace metals are a toxic group used to describe more than a dozen elements that are metals or metalloid [25-29] such as lead, nickel, zinc, chromium, cadmium, copper, iron and arsenic etc. Human activity affects the natural geological and biological redistribution of trace metals through pollution of air, water, animal, soil and plant [30-37]. The effect of trace metals on health including allergic reactions (e.g., beryllium, chromium), neurotoxicity (e.g., lead) and cancer (e.g., arsenic).

Arsenic is widely distributed in large number of minerals. Arsenic concentrations in soils and sediments are dependent on the geological conditions as well as on anthropogenic activities, e.g., the use of pesticides, mining activities, or industrial processes. Humans are exposed to many different forms of inorganic and organic arsenic species, arsenicals, in food, water and other environmental media.

Arsenic in foods occurs due to environmental contamination. Foods of animal or vegetable origin have a relatively low concentration. Furthermore, arsenic must be extracted from solid samples and presents in an aqueous form for speciation analysis by the more common methods such as ultrasonic system[38-42]. It has been routinely applied in laboratories as an alternative sample preparation procedure for challenging matrices that are usually recommended for atomic spectrometry. The physical effect produced by ultrasonic system (either bath or probe) includes cavitation, which consist of the nucleation, growth, and collapse of short-lived bubbles, which are formed in liquids/solutions that are exposed to low-frequency ultrasonic waves (<1 MHz). During sample preparation[43-47], cavitations favor the extraction of chemical species from solid materials through dissolution or complete mineralization performed at ambient temperature into dilute acid solutions. Therefore, the use of ultrasonic-assisted extraction into dilute acid solutions for the determination of macro- and micronutrients in agro-industrial samples avoids the use of concentrated acid solutions for sample digestion [48-50]. This review is to pave the way for simple and accurate method that suitable for routine application to determine of some metals available in such plant samples by flame atomic absorption spectrometry (FAAS) and some metal speciation (inorganic and organic compounds) analysis using flow injection-hydride generation atomic absorption spectrometry (FI-HGAAS). This will lead the development of a simple and robust sample preparation procedure that uses an ultrasonic-assisted extraction system for

the determination of total metals using FAAS to surplus conventional sample pretreatment procedures based on acid digestion.

2. MATERIALS AND METHODS

In many cases, arsenic has been chosen which is known to be toxic since ancient time, for example. This toxicity can make the high levels of arsenic found in plants growing on many contaminated sites problematic for plant consumers [16,17]. Many arsenic compounds present in the terrestrial and marine environments have been detected [18,19]. As(III), As(IV), methylarsonic acid (MA) and dimethylarsinic acid (DMA) are the predominant arsenic species found in terrestrial biota, including plants. Chronic exposure to arsenic, particularly inorganic arsenite (As(III)) and arsenate (As(V)), has been implicated in many physiological disorders and various types of cancers. Since the toxicity of arsenic depends on its chemical form, both speciation and quantitative determination of arsenic are essential.

The determination of arsenic in samples can be done by various techniques including atomic absorption spectrometry (AAS) [20], inductively coupled plasma-mass spectrometry (ICP-MS) [21,22], electrothermal atomization atomic absorption spectroscopy (ETAAS) [23,24], hydride generation coupled with atomic absorption spectroscopy (HGAAS) [25], or coupled with atomic fluorescence spectroscopy (HGAFS) [26], high performance liquid chromatography-inductively coupled plasma-mass spectrometry (HPLC-ICP-MS) [27], graphite furnace atomic absorption spectrometry (GFAAS) [28,29], inductively coupled plasma-atomic emission

spectrometry (ICPAES) [30], high performance liquid chromatography-hydride generation-inductively coupled plasma-mass spectrometry (HPLC-HG-ICP-MS) [31], ultraviolet-visible spectrophotometer [8] and electrochemistry [32]. The analytical techniques are suitable for determination of arsenic due to high precision, sensitivity and low detection limit. However, it is notable that HGAAS technique is widely used for determination of arsenic when compared with those mentioned techniques. HGAAS has been frequently used for direct determination of arsenic because of use, quick operation, high sensitivity, low cost and low detection limit. Literatures on determination of arsenic by FIHGAAS and other published methods are summarized.

3. RESULTS AND DISCUSSIONS

The extraction methods of plant commonly include hot water extraction (HWE), microwave assisted extraction (MAE), pressurized liquid extraction (PLE), ultrasonic solvent extraction (USE) and ultrasound-assisted extraction (UAE). Although the main advantage of applying microwave is that it is time saving but its disadvantage in homogeneous heating [46,47]. Thus, the use of an ultrasound is more convenient and affordable. Ultrasound processing presents a certain number of parameters that should be carefully studies in that they can influence the process. Ultrasonic frequency is one of important operating parameters and has a strong effect on extraction yield. In general, for ultrasonic cavitation, not all bubbles are capable of producing significant cavitation effects. The greatest coupling of the ultrasonic energy will occur when the natural resonance frequency of the bubble is equal to the ultrasonic frequency. The resonance frequency of the bubble is equal to

the ultrasonic frequency. The resonance frequency equation of extraction bubble was deduced by Huang et al. [48]. It suggested that under the conditions described to study ultrasonic extraction, the yield in liquid medium can reach a maximum value at the optimum ultrasonic frequency which helps to promote bubbles division by driving the bubbles into resonance. Therefore, determination of optimum ultrasonic frequency is a very important research subject, which may improve extraction yields for natural products.

4. CONCLUSION

Ultrasound-assisted extraction is a novel method to effectively extract the targeted components from plant products which has been proven to significantly increased extraction yield together with shorter time, lower temperature and smaller solvent. Recently, many studies have reported that higher extraction yields could be achieved when an UAE method was adopted on many plant products, such as rutin from flower buds of *Sophora japonica*, oil from tobacco (*Nicotiana tabacum* L.) seed, carvone and limonene from caraway seeds, polyphenols from black tea, extraction of carotenoids, pectins from grape pomace, D-pinitol from carob pods and vanillin from vanilla pods. Those studies mainly looked at optimization of other extraction conditions with regards to efficiency and/or yield.

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