Analytical Methods

Graphite nanocomposites sensor for multiplex detection of antioxidants in food

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1. Introduction

Antioxidants can be categorized into synthetic or naturally occurring compounds (Brewer, 2011; Iverson, 1995). The use of antioxidant preservatives in food is unavoidable, because they assure excellent quality and a pleasant appearance, odor, and taste for the consumer. This has become a concern, especially with the rapid growth of the processed food market where products require a long and stable shelf life. Synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tert-butylhydroquinone (TBHQ), and propyl gallate (PG) are common food preservatives used for this purpose. These compounds protect food from rancidity and discoloration by scavenging free radicals generated by chemical processes such as the peroxidation of oils and fats (Ziyaditnova, Saveliev, Evtugyn, & Budnikov, 2014). The chemical structures of BHA, BHT, and TBHQ are illustrated in Fig. 1.

According to the United States Food and Drug Administration (USFDA) regulations, the permissible levels of BHT or TBHQ in food (either alone or in combination with BHA) are limited to 200 μg g⁻¹ (Brewer, 2011). On the other hand, the levels of BHA alone are limited to 2–1000 μg g⁻¹. Safety assessment studies have shown that the use of BHA and BHT at high concentrations (above 3000 μg g⁻¹) potentially promotes cancer proliferation in animals (Iverson, 1995; Xiu-Qin, Chao, Yan-Yan, Min-Li, & Xiao-Gang, 2009). Hence, the determination and monitoring of these unavoidable additives in processed products are important for food safety. Various analytical procedures have been developed for the determination of these antioxidants, including high-performance liquid chromatography (Li, Meng, Zhao, & Yang, 2014), Fourier transform infrared spectroscopy (Goulart, Teixeira, Ramalho, Terezo, & Castilho, 2014), and gas chromatography methods (Wang et al., 2014). Although these methods are sensitive and selective, they are not suitable for on-site analysis and require significant investment in expensive instruments. The alternative electrochemical method is simpler, faster, and more sensitive. Moreover, this method can be adapted to novel technologies, such as screen-printed electrodes (SPEs), which can be useful for portable real-time on-site analysis.

Graphite is abundantly available and can be easily obtained/recycled from many commercial sources, such as pencils (Alipour, Reza, & Saadatirad, 2013) and used batteries (Appy et al., 2014). The good electrical conductivity and the renewable surface of graphite have made it a prospective working electrode material (Ramesh, Sivakumar, & Sampath, 2002). However, graphite suffers from a low overpotential activation energy (Wring & Hart, 1992), requiring additional potential to support the redox