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EDITORIAL

(Nano)bioelectroanalytical tools driven research in personalized medicine and nutrition

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In the realm of healthcare and nutrition, the shift towards personalized approaches has gained significant traction in recent years. Tailoring medical treatments and dietary recommendations to individual characteristics holds immense potential for improving outcomes and overall well-being. At the heart of this paradigm shift lies the need for robust analytical tools that can seamlessly integrate into the dynamic landscape of personalized medicine and nutrition.

Traditional diagnostic and nutritional assessment methods often fall short in capturing the intricacies of individual variability. However, scientific advancements in fields such as genomics, metabolomics, and microbiomics have enabled a deeper understanding of the unique molecular and physiological signatures that distinguish individuals, and the translation of this knowledge into practical applications requires analytical tools capable of non-invasively extracting this complex, multi-omic level information with precision and reliability. The field of electrochemical biosensors coupled to micro/nano-structured materials has witnessed remarkable breakthroughs, with potential to revolutionizing the landscape of decentralized and personalized medicine and nutrition through noninvasive, simple, and affordable methods.

The Topical Collection "(Nano)bioelectroanalytical tools driven research in personalized medicine and nutrition" brings together diverse contributions showcasing the latest advances in the development of devices for the detection of various biomarkers such as proteins, nucleic acids, and neurotransmitters. These contributions (one review and four research articles) delve into innovative electrochemical biosensing approaches, encompassing new surface chemistries and nanomaterials, different bioreceptors such as antibodies and aptamers, as well as novel technologies such as the CRISPR-Cas system, to pave the way for more effective and personalized interventions. All the articles can be accessed through the following link: https://link.springer.com/collections/ieiiaeeghe

A review article by J. Tkac et al. offers a comprehensive exploration of MXenes as novel 2D nanomaterials for designing electrochemical devices, emphasizing their potential in healthcare applications. The review begins with a detailed overview of MXenes, covering their physico-chemical features, synthesis methods, and possible interfacial modifications. The unique physico-chemical characteristics of MXenes make them appealing for various practical applications, especially in healthcare. The article delves into the hot scientific discipline of using MXenes for healthcare applications, focusing on the detection of low and high-molecular weight analytes, including metabolites, DNA/RNA, proteins, cells, exosomes, and viruses, using electrochemical sensors and biosensors. The work addresses the challenges facing MXene-based devices, such as reproducible synthesis, stability in different environments, and biocompatibility issues. It highlights the low cytotoxicity of MXenes and suggests approaches to enhance stability and biocompatibility. The discussion emphasizes the bright future of MXene interfaces in healthcare once challenges related to synthesis, stability, and biocompatibility are effectively addressed, showcasing their potential in revolutionizing healthcare applications.

In the context of personalized nutrition, C. Cristea with co-authors address the global issue of food allergies, focusing on the life-threatening implications of peanut allergies and the challenges posed by mislabeling and

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cross-contamination during food processing. The study presents an electrochemical aptasensor for the sensitive detection of Ara h1 peanut allergen. The method involves immobilizing a specific aptamer on the gold surface of screen-printed electrodes. To improve aptamer insertion and reduce fouling effects, a layer of *p*-aminothiophenol (*p*-ATP) is immobilized on the same surface. The resulting disposable aptasensor enables the electrochemical detection of Ara h1 protein in the presence of a redox probe, demonstrating excellent selectivity and sensitivity with limits of detection in the nanomolar range. This aptamer-based device represents a promising "on-site" method for quantitative allergen risk assessment, offering a fast and easy-to-use tool for improving consumers' quality of life and addressing the challenges associated with allergen labeling regulations on a global scale.

A novel conductive ink based on carbon black and poly(vinyl alcohol) is reported by Janegitz et al. for the fabrication of electrochemical sensors and biosensors. The electrodes prepared with this ink were subsequently modified with Pd nanoparticles to enhance electrical conductivity and reaction kinetics and were applied to the determination of Parkinson's disease biomarkers, specifically epinephrine by direct electrochemical detection and α-synuclein using an immunosensing approach. The immunosensor was successfully applied to blood serum samples, demonstrating a linear range that includes concentration levels useful for diagnosis. The proposed platform presents a cost-effective, disposable, and efficient solution for Parkinson's disease diagnostics, offering quick preparation, ease of operation, and acceptable reproducibility, making it a valuable addition to the set of electrochemical devices potentially useful for healthcare applications.

D. Tang et al. report an electrochemical immunoassay for the quantitative monitoring of human epidermal growth factor receptor 2 (HER2), a critical biomarker associated with various cancers. The assay is conducted on a screen-printed carbon electrode modified with iron nitrogen-doped carbon (FeNC) nanozyme as a peroxidase-mimicking. The approach involves a sandwich format with an anti-HER2 monoclonal antibody immobilized on the conductive surface as capturing receptor and biotinylated anti-HER2 polyclonal antibody as signaling. Streptavidin-glucose oxidase (GOx) conjugate is then introduced, in such a way that in the presence of glucose, 3,3′,5,5′-tetramethylbenzidine (TMB) is oxidized through H_2O_2 production with the assistance of GOx and FeNC nanozyme. The oxidized TMB is detected via chronoamperometry, demonstrating a sensitive electrochemical response with a low limit of detection. The FeNC nanozyme-based strategy offers high selectivity, long-term stability, and a new avenue for protein diagnostics. The proposed method, with its ingenious indirect detection strategy, holds promise as a generalized approach for detecting various biomarkers, facilitating more effective early screening and diagnosis of common diseases within the realm of precision medicine.

A highly sensitive biosensor for microRNA-21 was developed by Z. Lin et al. leveraging the specificity and trans-cleavage activity of CRISPR/Cas13a, coupled with the amplification efficiency of hybridization chain reaction (HCR) and magnetic-assisted enrichment. The CRISPR/Cas13a system recognizes target RNA with high specificity and triggers trans-cleavage, generating an initiation strand that binds to the probe on the surface of nanomagnetic beads. Subsequently, HCR produces long double-strand DNAs (dsDNAs) for signal amplification. $Ru(phen)_3^{2+}$ is inserted into the dsDNAs, acting as the electrochemiluminescence (ECL) indicator. The biosensor exhibits a good linear correlation between ECL intensity and the logarithm of miRNA-21 concentration and was successfully applied to detect miRNA-21 in the urine of acute kidney injury (AKI) patients, showcasing its potential for early diagnosis of AKI with high sensitivity and stability.

Overall, the five articles compiled within this Topical Collection present an overview of how researchers are committed to advancing the frontiers of knowledge, exploring innovative solutions that can bridge the gap between basic developments and the solution of social needs. These contributions highlight the crucial role of new, noninvasive analytical methods in meeting the evolving demands of the fields of precision medicine and nutrition, emphasizing the scientific foundations that support their adoption. We realize that the current landscape necessitates a paradigm shift in our approach to diagnostics and nutritional assessments, urging the adoption of cutting-edge technologies to meet the demands of the personalized medicine and nutrition revolution. And more particularly, the selected contributions demonstrate the progressive enhancement of the capabilities and opportunities of electroanalytical chemistry, derived from both its versatility and its open nature to connect with different disciplines and venture into unexplored terrain, and to value the power of information at the molecular level.

And all of this means that electrochemical nanobiotools are currently positioned among the most appropriate technologies to face the challenges of advancing both in research and in the implementation of precision medicine and nutrition. We are confident that the small but special sample of contributions that make up this Thematic Collection will add even more value to this important and exciting topic and will inspire new scientists to work on it.

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Guest Editors

Declarations

Conflict of interest The authors declare no competing interests.