

Selective and sensitive determination of neopterin in biological fluids using magnetic silica-supported molecularly-imprinted polymers

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ABSTRACT

Neopterin (NPT) is a key biomarker of immune system activation and holds significant importance in the diagnosis and monitoring of various clinical conditions. In this study, a novel magnetic silica-supported molecularly imprinted polymer (MIP-MS) was synthesized via surface imprinting and integrated with UV–vis spectrophotometry for the selective extraction and quantification of NPT in human serum and artificial cerebrospinal fluid. Comprehensive characterization was carried out and the results confirmed the successful fabrication of the MIP layer with well-defined structural and surface properties. Adsorption kinetics and isotherm studies were best fitted by the pseudo second-order ($R^2 = 0.9997$) and Langmuir model ($R^2 = 0.9987$), respectively and the results revealed the presence of specific recognition sites on the MIP-MS for NPT, resulting in adsorption capacity of 98.3 mg/g and imprinting factor of 4.77. Additionally, the MIP-MS exhibited outstanding reusability, retaining its performance over 10 adsorption-desorption cycles. The developed method demonstrated excellent sensitivity, with a wide linear range (3–300 nM), a detection limit of 1.18 nM and a recovery range of 97.6 %–100.4 %, accompanied by a relative standard deviation below 5.0 %. The findings suggest that the proposed MIP-MS coupled with UV–vis spectrophotometry provides a cost-effective, rapid, and highly selective alternative for NPT detection in biological samples.

1. Introduction

Neopterin (NPT), is a pteridine derivative and a major biomarker of immune system activation, synthesized by human monocytes and macrophages when stimulated by interferon-gamma (IFN- γ) [1]. NPT, a catabolic product of guanosine triphosphate (GTP), is secreted after pro-inflammatory cytokine signaling and is commonly acknowledged as a central player in immune-mediated disorders [2]. In different pathological states, elevated NPT levels in biological, particularly, serum, urine, cerebrospinal fluid, and synovial fluid were documented during viral and bacterial infections, autoimmune diseases, cardiovascular pathologies, neurodegeneration and malignancies [3]. For example, the concentration of NPT in the blood serum of untreated HIV patients is significantly elevated, reaching approximately 90 nM, whereas healthy individuals typically exhibit levels ranging between 5 and 10 nM [4]. As an immune activation score, it holds high diagnostic value due to its ability to reflect immune activation dynamics in a particular condition, making it indispensable in disease monitoring and prognosis scenarios.

A number of methods have been developed for the determination of NPT in biological fluids, with each method having advantages and disadvantages. One of the most used methods high-performance liquid chromatography (HPLC) due to its high sensitivity and reliability [5]. However, its need for complicated samples preparation, time-consuming, and require skilled personnel. Enzyme-linked immunosorbent assay (ELISA) [6] and radioimmunoassay (RIA) [7] have been used extensively, but they have disadvantages of lengthy and time-consuming protocols, costly reagents, and requirement for specialized equipment. Furthermore, there are environmental and safety concerns with the usage of radioactive elements in RIA. Electrochemical sensors, especially those using potentiometric [8] or differential pulse voltammetry (DPV) detection [9], are fast and low-cost alternatives; however, their selectivity can be limited by the presence of structurally similar compounds, including biopterin and xanthopterin. Fluorescence-based methods have also been employed for NPT detection, owing to its native fluorescence, but these can be hindered by quenching effects and matrix interferences [10]. Surface-enhanced

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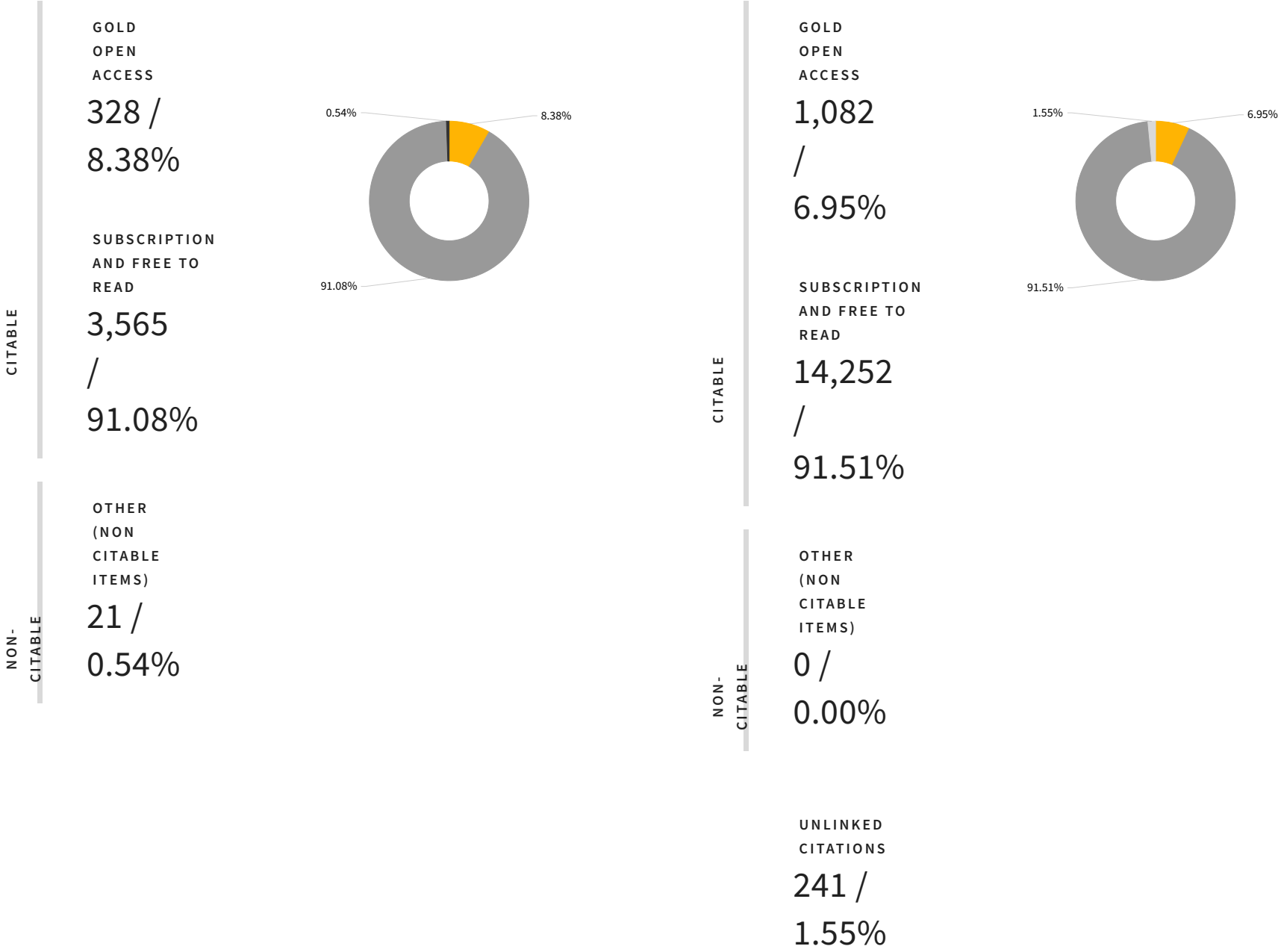
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